

THE MAGAZINE THAT FEEDS MINDS

HOW IT WORKS

INSIDE

SCIENCE ENVIRONMENT TECHNOLOGY TRANSPORT STORE SPACE

BATTLESHIPS

Warships with the advanced firepower to rule the seas

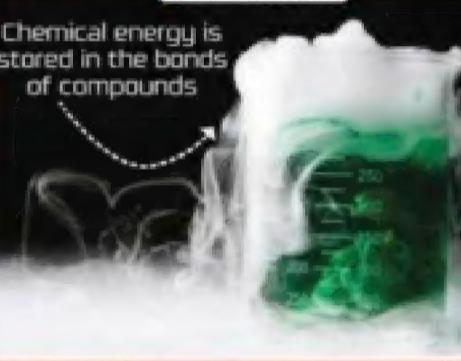
ELASTIC



KINETIC



CHEMICAL



Chemical energy is stored in the bonds of compounds

GRAVITATIONAL



HEAT



Whenever something heats up or cools down it uses energy

ENERGY EXPLAINED

EVERYTHING YOU NEED TO KNOW ABOUT THE LAWS THAT GOVERN THE ENTIRE UNIVERSE

SOUND



A sonic boom generates an explosion of sound energy

ELECTRICAL

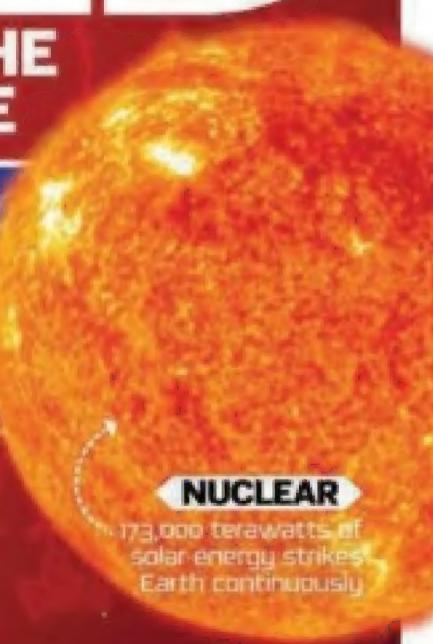


The average lightning bolt contains 5 billion joules of energy

BACTERIA

There's more to these organisms than just food poisoning...

NUCLEAR



173,000 terawatts of solar energy strikes Earth continuously

MISSION TO JUPITER

THE 8-YEAR JOURNEY TO THE JOVIAN SYSTEM EXPLAINED

+ LEARN ABOUT

- FJORDS
- PAYLOADS
- NEXUS 7
- SALMON
- TYRES
- TRITON
- HORNETS
- MICROFILMS
- CARBON DATING
- BIONIC HUMANS
- TRACHEOTOMIES
- FUEL SYSTEMS



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ISSUE 51

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Energy is defined as the ability to do work, but what does that really mean? We know energy is a really useful thing: it turns food into fuel for our bodies, it turns sunlight into power for plant growth, it releases arrows from bows, moves the compass needle when you're lost and so much more. So this issue, we've got down all the essential energy basics you need to better understand life, the universe... and, well, everything! Once you've grasped a few simple rules you may see physics in a whole new light.

We also take a look at the planet's biggest terrestrial animals and ask just

how they have adapted to survive despite – or because of – their immense size. These behemoths of the natural world are quite remarkable in their specialisations and abilities, and we're sure you'll thoroughly enjoy reading about their supersized biology.

Enjoy the issue.



Helen
Helen Porter
Editor

Meet the team...



Robert
Features Editor

I had a hairy time this month ducking the Ankylosaurus's deadly tail. Luckily I got the information I needed for an article on the dino.



Jackie
Research Editor

I've really enjoyed the bionics feature – the advancements being made in that field are amazing. Check it out on page 52!



Marcus
Designer

I've had a wonderful time learning more about the JUICE project, which is tasked with exploring Jupiter and its incredible moons.



Adam
Senior Sub Editor

A sockeye salmon doesn't have it easy, but nobody can accuse it of leading a dull life, as you'll discover in our fishy Environment feature.



What's in store...

The huge amount of information in each issue of *How It Works* is organised into these key sections:

Science
Uncover the world's most amazing physics, chemistry and biology

Technology
Discover the inner workings of cool gadgets and engineering marvels

Transport
Everything from the fastest cars to the most advanced aircraft

Space
Learn about all things cosmic in the section that's truly out of this world

Environment
Explore the amazing natural wonders to be found on planet Earth

History
Step back in time and find out how things used to work in the past

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Mission to Jupiter

Meet the experts...

Rik Sargent

Going supernova

This issue Rik from the Institute of Physics reveals what happens at the end of a massive star's life, stage by stage, resulting in the biggest explosion in the universe, before taking some of your questions in the Brain dump.



Ella Carter

Fjords

Ella is a marine biology and oceanography expert, with a degree in the subject, and this issue she reveals the spectacular fjord formation process as well as the wildlife that calls it home.



Luis Villazon

Nature's giants

From elephants to giraffes and big cats, How It Works regular and zoology specialist Luis gets to the heart of the biology of the planet's largest animals, explaining how they survive.



Alexandra Cheung

Energy

Our cover feature this issue comes courtesy of science explainer Alex who brings the laws of energy into focus, explaining why it cannot be created nor destroyed.



Laura Mears

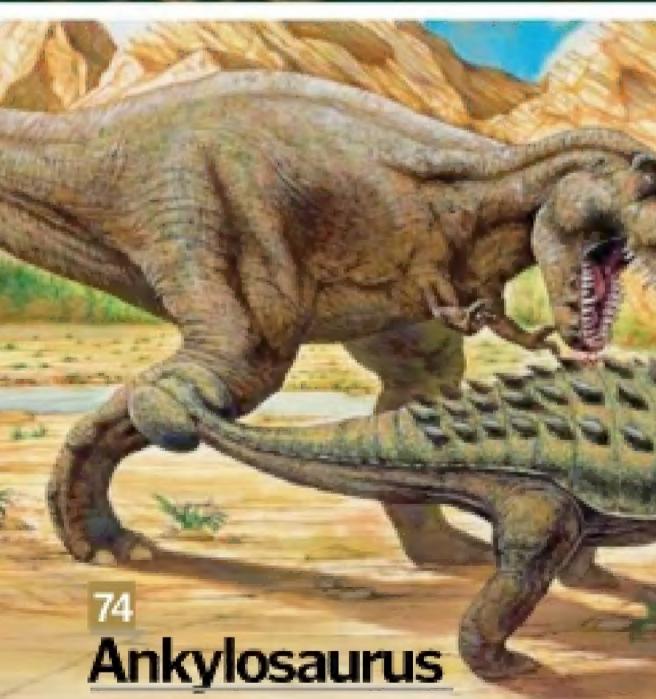
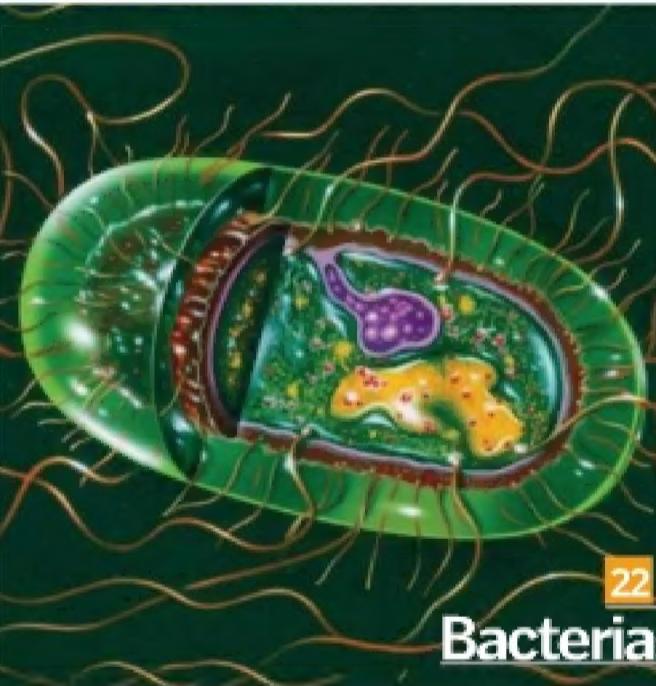
Bionic humans

Biology guru Laura is taking a close-up look at the fascinating world of biomechanical engineering revealing how prosthetics and artificial organs are currently on the verge of something big.

How do you make a smartphone water-resistant? Find out now on page 61



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The place where we answer all your most curious questions

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...hit a hole-in-one and plaster up a hole in the wall to perfection

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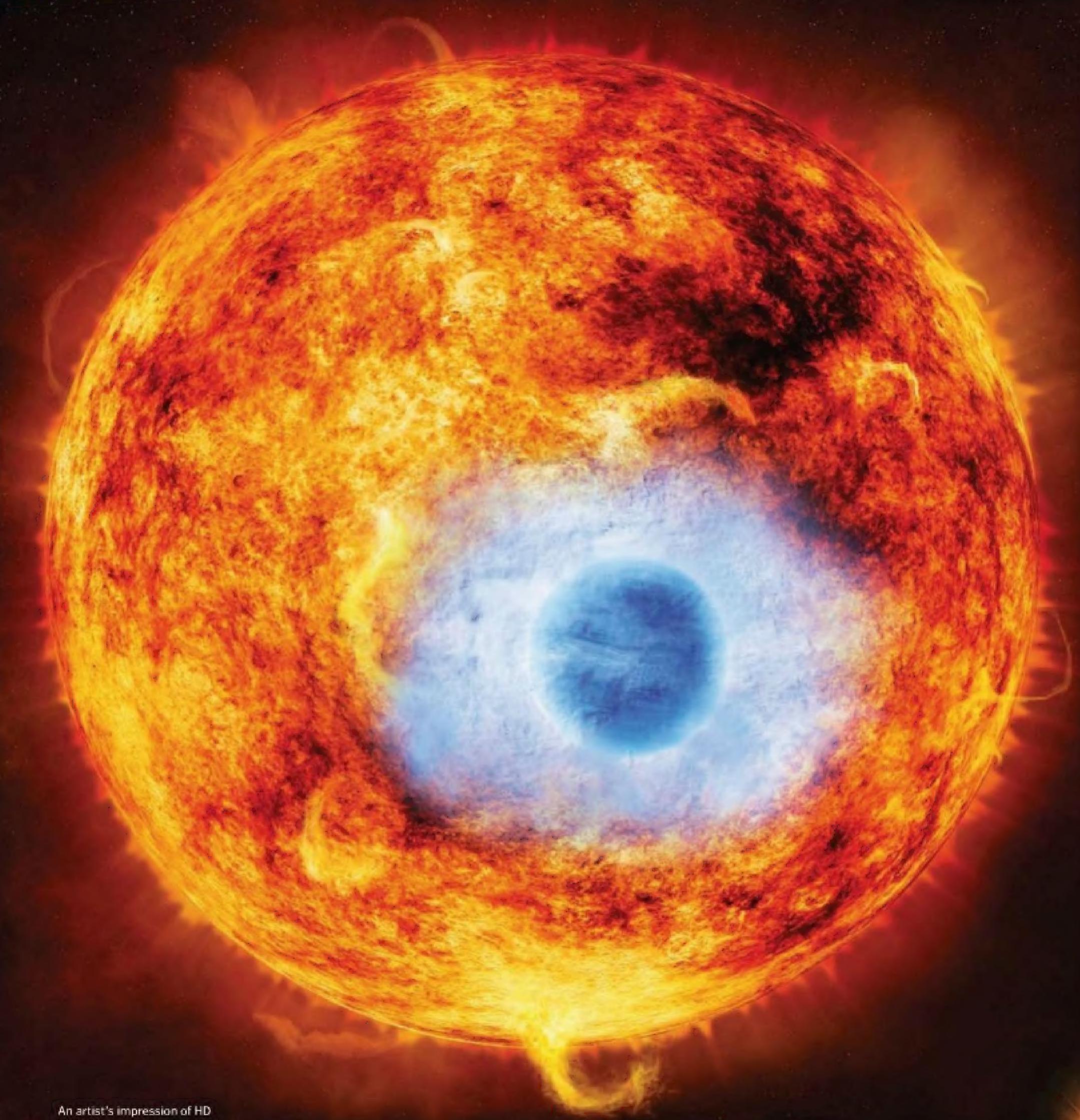
Letters

Our readers have their say on all things science and tech

HOW IT WORKS

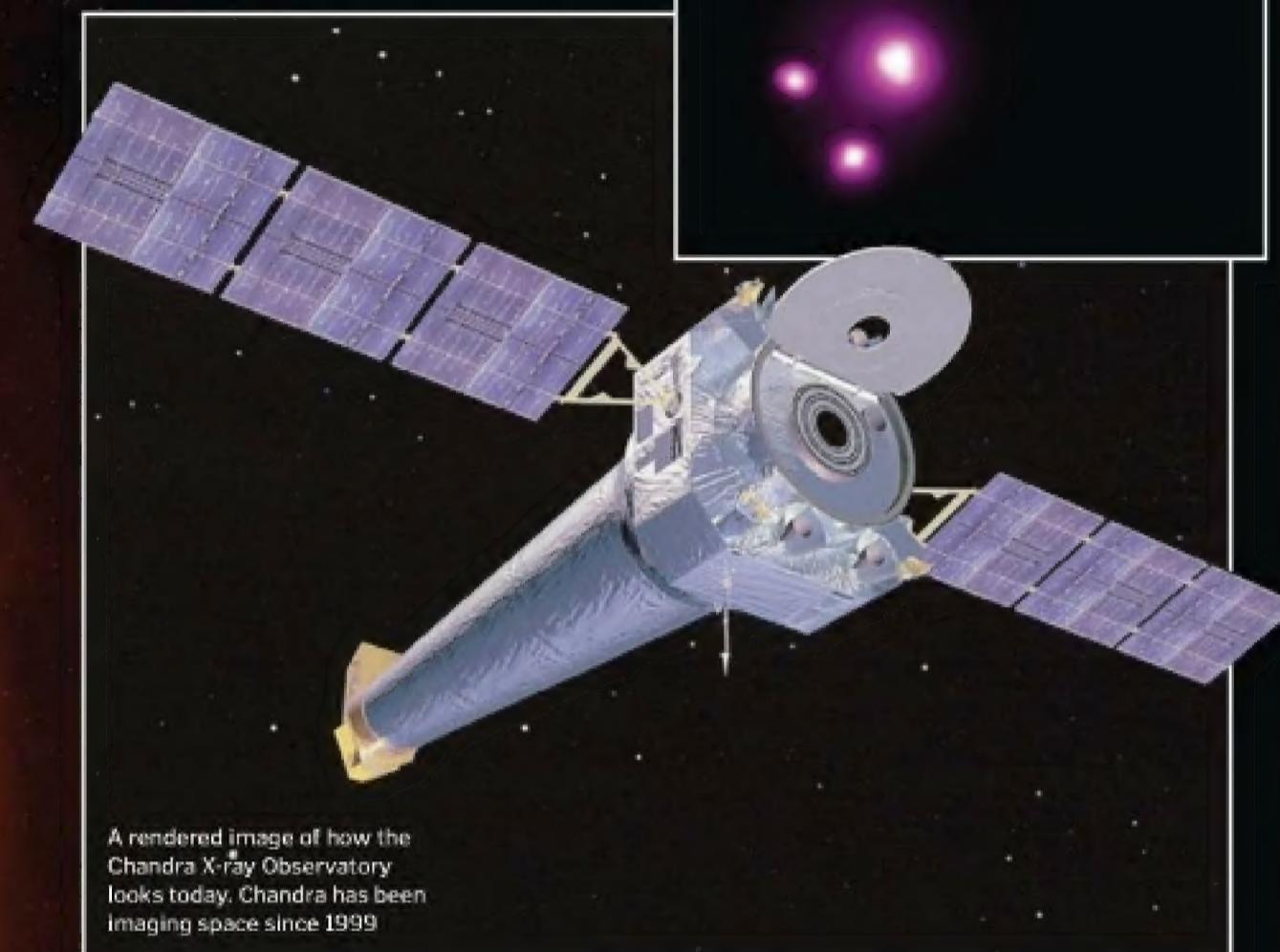


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An artist's impression of HD 189733b, a blue, Jupiter-sized exoplanet orbiting its Sun-like star

The main star in the HD 189733 system has a smaller companion star, detected for the first time through Chandra



A rendered image of how the Chandra X-ray Observatory looks today. Chandra has been imaging space since 1999

Alien 'Jupiter' discovered

A Jupiter-like planet orbiting a star at close range is snapped with X-rays



For the first time ever NASA has imaged an exoplanet passing in front of its parent star with X-rays (see main image). The feat – which was achieved by NASA's Chandra X-ray Observatory – has been celebrated within the astronomical community as, up until now, exoplanets such as this one have only been captured using optical light.

Speaking on the breakthrough, Katja Poppenhaeger of the Harvard-Smithsonian Center for Astrophysics said: "Thousands of planet candidates have been seen to transit in only optical light. Finally being able to study one in X-rays is important because it reveals new information about the properties of an exoplanet."

Interestingly, closer analysis of the results has revealed that the planet, which currently

has the rather technical name of HD 189733b, is akin to a hot version of our Solar System's Jupiter – but 30 times closer to its star than Earth to the Sun. This proximity means that the planet orbits its star once every 2.2 days and has a surface temperature of over 1,000 degrees Celsius (1,832 degrees Fahrenheit).

Further, studies of the exoplanet have shown that its blue colour is the result of a high presence of silicate particles in its atmosphere. NASA scientists believe this is because the planet's atmosphere rains silicate glass sideways within winds of over 7,000 kilometres (4,350 miles) per hour.

Moving forward, NASA intends to continue investigating the new planet and its system's main and companion stars, determining more about the relationship between them and how they influence one another.

Scientists grow heart



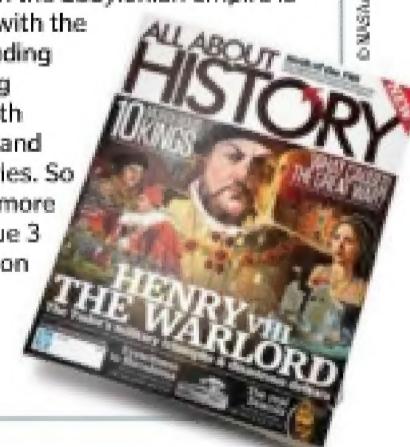
Scientists from the University of Pittsburgh, PA, have managed to grow a functioning mouse heart from pluripotent stem cells – adult stem cells that act like embryonic ones. The team achieved this by stripping a mouse heart of its cells and then replacing them with human stem cells. The result was that the heart began to beat again just as before. The team – who published the research results in the journal *Nature Communications* – said it could lead to induced pluripotent stem (iPS) cells being used in organ transplants in the future, while hearts and other major organs could also be made to test drugs in laboratories. Research team member Dr Lei Yang commented on the publication of the results: "Scientists have been looking to regenerative medicine and tissue engineering approaches to find new solutions for this important problem. The ability to replace a piece of tissue damaged by a heart attack, or perhaps an entire organ, could be very helpful for these patients."



New All About History lands!



If you ever wondered what life was like fighting under Henry VIII then the latest issue of *All About History* is for you. This month they've gone full-on Tudor to produce the definitive feature on this famous monarch's military record, with everything from his greatest triumphs to his most bitter defeats. This edition also counts down ten of the most murderous monarchs and talks to the last survivor from the Enola Gay which dropped the atomic bomb on Hiroshima. If all the blood and destruction gets too much, a feature on the Babylonian empire is the perfect antidote, with the city of Babylon – including those famous Hanging Gardens – detailed with stunning illustrations and some fascinating stories. So for all that and much more be sure to pick up issue 3 of *All About History*, on sale 22 August 2013, available from supermarkets and all good newsagents.





"In answering why primordial soup is wrong you quickly get to the question 'What is life?'"

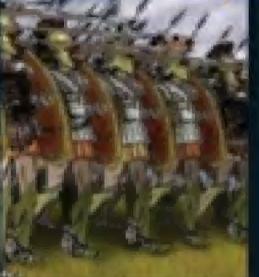
Creation: The Origin Of Life/The Future Of Life is available now priced £20 at all good bookshops. *Inside Science* airs every Thursday at 4.30pm on BBC Radio 4.

This day in history

12 September: How It Works issue 51 goes on sale, but what

490 BCE

Greek victory
The Battle of Marathon concludes with the combined forces of Ancient Greece defeating the invading Persians.



1309

Battle for Gibraltar
The First Siege of Gibraltar takes place with Castile taking it from the Emirate of Granada.

1609

Up the Hudson
English explorer Henry Hudson begins a trip along the Hudson River in Canada, aboard the Halve Maen (Half Moon).



1846

Poetry in motion
Famous poet Elizabeth Barrett elopes with playwright Robert Browning.

1885

Walkover
In the 1885-1886 Scottish Cup, Arbroath defeat Bon Accord by 36 goals to 0.

1940

Ancient art
Well-preserved cave paintings dating from the Palaeolithic period are discovered in Lascaux, France.

1958

First chip
US electrical engineer Jack Kilby demonstrates the world's first integrated circuit.



1964

Grand canyons
Canyonlands in Utah is granted official national park status.



2005

Disney in China
The Hong Kong branch of Disneyland opens for the first time.

2011

Lest we forget
The 9/11 Memorial is opened to the public, ten years after the terrorist attack took place.

The man inside science

Star of the BBC's *Inside Science*, Adam Rutherford talks about the origins of life, what we can learn from a paper cut and the importance of non-stick frying pans

Tell us about your new book *Creation*.

The idea for the book spawned about ten years ago when I was still working in the lab. My beat has always been genetics and evolution in terms of being a journalist and two advances happened in molecular biology that I found extraordinarily interesting. The first is the origin of life. We have now got to a stage where, because of our understanding of the cell – of the mechanics of metabolism and how DNA works – we've got a pretty robust model of how life itself originated. So we can begin to test all of the basic principles of cells, what they do and how they could have come about.

The [second thing] is our ability to manipulate DNA in what we now call synthetic biology. That field has really blossomed over the last ten years. Now both those things are inherently related. The science of the origin of life is about reconstructing cells in the way we think it might have happened 4 billion years ago. And synthetic biology is essentially doing the same but just for specific purposes. So it produces cells that have a function that is useful to us. The modern era of molecular genetics has given birth to these two fields and I wanted to put them back-to-back.

Do you subscribe to a specific theory as to how LUCA was generated?

There are a few different models as to how LUCA came to be and I end up pinning my colours to a specific and [unorthodox] view. And that is not the culturally pervasive idea of the primordial soup. The reason that won't work is because of physics. When you prime that soup so that interesting reactions will take place, they may well occur, but the problem is they won't happen again. That is not what life does.

In answering why primordial soup is wrong you very quickly get to the question 'What is life?' – and interestingly there isn't a definition. I have gone through the various ideas of what life is about, but there's a fundamental underlying process that enables everything life does: life captures energy from the environment and uses it. I think that is the most basic test of what living things do. What I am talking about is how you get metabolism first.

So then you begin to look for a place where you might see naturally occurring chemistry

decades to fully understand, involves the birth of new cells. Those cells are not born from nothing – they are born from existing cells. And those cells were born from existing cells and so on until you get back to your first cell, which was a fertilised egg. And you can track that exact same process back in your parents and their parents and every member of our species, and on to every organism that has ever existed. So that cell which is patching up a little hole on your finger has a lineage, a direct ancestry which we can trace back 4 billion years to the first cell that ever existed. We call that cell 'LUCA' (Last Universal Common Ancestor) – the mother of everything that has ever lived.

Do you approach the origins of life in a chronological order?

Yes, kind of. I start off with a paper cut actually, as I want to get readers thinking about the monumental significance of the mundanity of living. That if you cut your finger, after a couple of days it is patched up and that, after a month or so, it is fully healed and, after a few months, it will be indistinguishable to how it had been before. That process, which is incredibly sophisticated and has taken researchers

that resembles the most fundamental energy-generating process that cells do, and these are deep-sea hydrothermal vents. It's a really interesting model of how life might have begun.

What is your new radio show, *Inside Science*, all about?

It's a new slot on Radio 4 where we wanted to reflect how science has changed over the past ten years. We wanted to be more reflective of how science works as a process. So in general we wanted to move away from merely looking at what studies had come out and instead look at how experiments develop, how scientists think and what the environment is like during the scientific method. We aim to detail the truth about the scientific process warts and all.

If there were one piece of technology you couldn't live without what would it be?

I'm tempted to say the thing I'm holding right now – my smartphone – although that is so obvious. So I would say something like the toaster. Or the oven. What would we do if we couldn't cook anything? In fact, that is a good answer. We evolved out of being able to digest raw food about 400,000 years ago, so without an oven or a toaster or a frying pan we would be absolutely shafted. I'm going to go for the non-stick frying pan!

What projects are you looking forward to?

Next week I'm filming a slot for BBC's *The One Show* on genetically modified foods, where I shall be arguing Britain should be adopting GM crops. Following that I will be working on my second book, which I have just started writing. However, that's going to have a two-year gestation period, so don't hold your breath!

GLOBAL EYE 10 COOL THINGS WE LEARNED THIS MONTH



Sleepless nights increase temptation

Just one sleepless night can make you crave junk food the next day. A sleep study showed that activity in the area of the brain associated with the desire to eat was boosted in people who haven't had enough sleep. In the area associated with judging and evaluating whether or not to eat, meanwhile, activity was reduced. This means that we find it harder to turn down the offer of indulgent snacks and treats after a bad night's sleep. This study could be used to explain the apparent link between sleeplessness and obesity.



Talking while driving is dangerous

Although driving and using a hand-held device has been illegal in the UK since 2003, hands-free kits are legal. But now scientists researching the subject of distracted driving have suggested hands-free devices can be just as risky. Studies into 'cognitive load' indicate that when talking to someone we can't see, we subconsciously produce a mental picture of them, which demands extra brainpower and as a result deprives our other faculties.

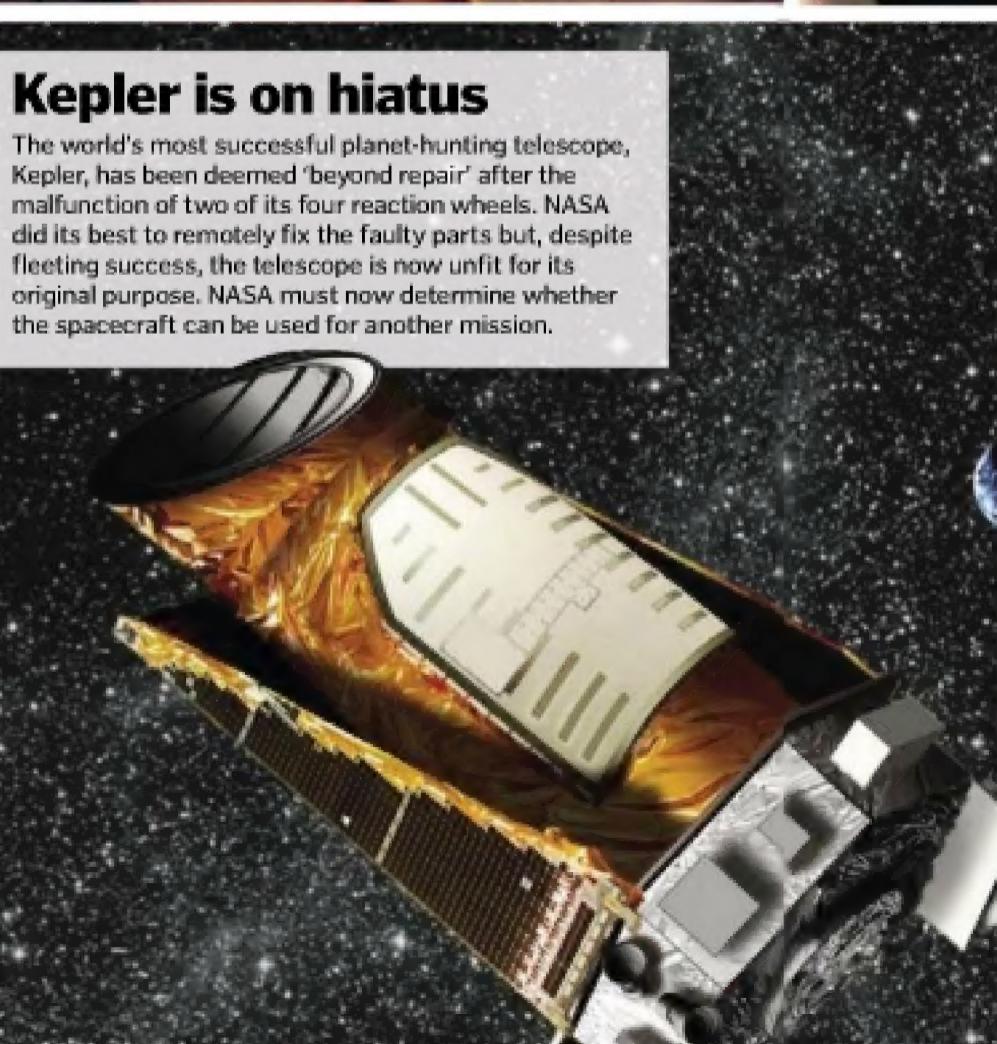
'LEGO' holds the key to future manufacturing

A team at MIT has used the concept of a popular children's construction set to revolutionise the composite manufacturing process. By clipping together 2D shapes (such as crosses) made out of a super-light material, future material engineering could include the production of giant single units. Each piece - made up of millions of interlocking building blocks - would be tougher than current composites but much lighter, with huge potential for aircraft and spacecraft design, for instance.



Kepler is on hiatus

The world's most successful planet-hunting telescope, Kepler, has been deemed 'beyond repair' after the malfunction of two of its four reaction wheels. NASA did its best to remotely fix the faulty parts but, despite fleeting success, the telescope is now unfit for its original purpose. NASA must now determine whether the spacecraft can be used for another mission.



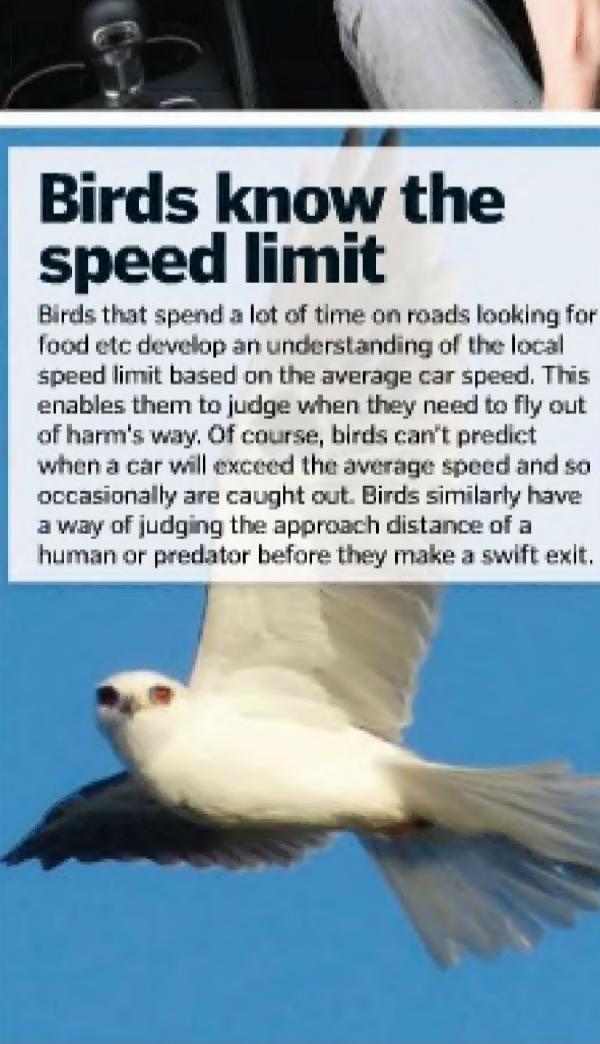
Superfast internet is coming to cars

Audi has become the first car manufacturer to include a 4G data connection in a production vehicle. The first model to debut this tech will be the Audi S3 Sportback (pictured here) and from November 2013 the full A3 range will feature superfast 4G/LTE data transfer. This development will enable high-quality in-car connectivity for lag-free web surfing while on the go.



Birds know the speed limit

Birds that spend a lot of time on roads looking for food etc develop an understanding of the local speed limit based on the average car speed. This enables them to judge when they need to fly out of harm's way. Of course, birds can't predict when a car will exceed the average speed and so occasionally are caught out. Birds similarly have a way of judging the approach distance of a human or predator before they make a swift exit.



'Unicorn of the sea' has been snapped

Divers off Tasmania have captured rare photos of a 30-metre (98-foot) sea creature that glows in the dark. The giant pyrosome (*Pyrostremma spinosum*), which is similar to the more common salp, is so rare it has been dubbed the 'unicorn of the sea'. Like plankton, pyrosomes are free-swimming tunicates found in the upper layers of the open ocean. All pyrosomes (*Pyrosoma atlanticum* is pictured) comprise a tube-shaped colony of tiny filter feeders called zooids enclosed in a kind of jelly.



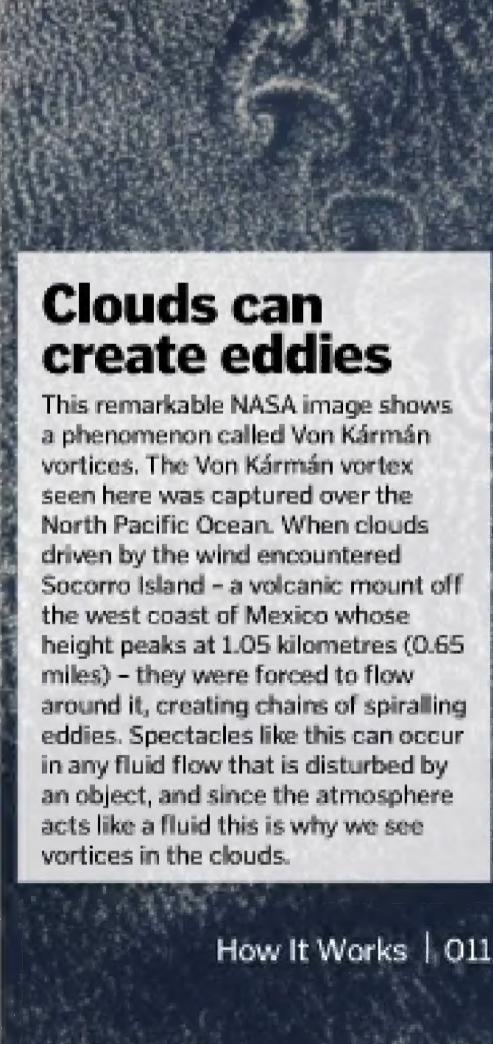
Tree frogs use umbrellas

Frogs are ectotherms, which means they use their external environment to maintain a constant body temperature because they do not have an internal thermostat like humans and other endotherms. Amphibians bask in the Sun to warm up or find shade or water to cool off. While it's not unusual to find tree frogs hopping around when it's damp, during tropical downpours they seek out shelter as they're not the best swimmers - they lack webbed feet and are often small enough to be washed away. It turns out they can be resourceful though, as this individual from Indonesia proves. The tiny frog protected itself during one particularly heavy shower by gripping a leaf and holding it like an umbrella angled into the rain.



Clouds can create eddies

This remarkable NASA image shows a phenomenon called Von Kármán vortices. The Von Kármán vortex seen here was captured over the North Pacific Ocean. When clouds driven by the wind encountered Socorro Island - a volcanic mount off the west coast of Mexico whose height peaks at 1.05 kilometres (0.65 miles) - they were forced to flow around it, creating chains of spiralling eddies. Spectacles like this can occur in any fluid flow that is disturbed by an object, and since the atmosphere acts like a fluid this is why we see vortices in the clouds.



DID YOU KNOW? A lightning bolt contains 5 billion joules of energy – enough to cook 100,000 slices of toast


ENERGY EXPLAINED

Get back to basics and find out how energy underpins every process in the universe



On an intuitive level, we all know that energy is what makes things happen, causing the Sun to shine, allowing plants to grow, cooking food on a stove or making a basketball bounce. Whenever something heats up, cools down, moves, grows, makes a sound or changes in any way, it uses energy. And from taming fire to powering smartphones, human civilisation relies on our ability to manipulate energy. But pinning down exactly what energy is can be tricky.

Grab a textbook and you'll find energy described as 'the ability to do work'. Work in this context is defined as exerting a force on an object over a distance. Lifting a cardboard box off the ground constitutes work, however

continuing to hold it there – although requiring effort on your part – is not work.

When work is done to an object, it gains energy. This energy is called kinetic energy if it's associated with the object's motion, as with a football speeding through the air after you kick it. When you pick up the box it is said to have gained potential energy, stored by virtue of its elevation above the ground. If you let go (mind your toes!), the box will fall, losing potential energy as it loses height, and gaining kinetic energy as it picks up speed.

One of energy's fundamental properties is that it cannot be created nor destroyed, only transformed from one type to another. Potential energy can turn into kinetic energy

and vice versa limitless times. Further, mechanical, sound, heat, electromagnetic, light, chemical and nuclear energy can all be converted from one into the other.

But while you can't destroy energy, you can certainly waste it through inefficiency. When you drive a car, for example, chemical energy stored in the fuel is converted into first thermal energy and then kinetic energy which turns the car's wheels. But not all of the chemical energy released from the fuel goes into making the vehicle move. Some is converted to heat and sound, and some is used to displace air around the car – ie air resistance. Once this has occurred it's very hard to turn this wasted energy back into something useful.

Energy in a rollercoaster

Find out how a rollercoaster takes potential and kinetic energy for a ride

3. Climbing

As the cart is pulled up the slope, the energy provided by the motor is stored away as potential energy.

2. Setting off

Approaching the first slope, the rollercoaster carriage has very little kinetic or gravitational potential energy.

1. Mass

The rollercoaster cart's mass determines how much energy is required to move it, as well as how much potential energy it can store.

4. At the top

Edging slowly past the highest point, the rollercoaster train has high potential energy but low kinetic energy.

5. On a roll

As the car whizzes down the slope, its potential energy rapidly transforms into kinetic energy.

6. Wasted energy

At each stage, some of the car's kinetic energy is lost to air resistance or dissipated as heat (through friction) and sound.

7. Low point

At the bottom of the slope, the car's potential energy is at its minimum while its kinetic energy peaks.

8. Back up

The rollercoaster carriage slows as it climbs the next peak, gradually converting kinetic energy back into potential.

Einstein's big idea

In 1905, Einstein revolutionised physics with a jaw-dropping revelation: matter and energy are one and the same. This fact is immortalised in the world's most famous equation: $E=mc^2$. Under the right conditions, energy can be converted into matter and vice versa. This energy comes from the ultra-strong bonds holding protons and neutrons together in atomic nuclei. The c in the equation represents the speed of light – about 1.13 billion kilometres (700 million miles) per hour – so even an object with tiny mass contains a huge amount of energy. If you could turn every atom of a paperclip into energy, you would release as much energy as the atomic bomb that obliterated Hiroshima in 1945. Doing so would, however, require extreme temperature and pressure conditions that are impossible on Earth.

c
The speed of light in a vacuum: is around 300,000,000m/s (983,600,000ft/s).

$$E = mc^2$$

E
E is energy, which is measured in joules.

m
m represents mass, measured in kilograms.

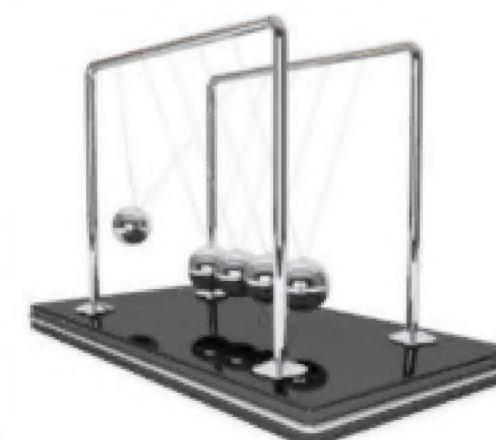
Conservation of energy

One of our universe's most basic principles, the law of conservation of energy states that energy can be neither created nor destroyed. That is, the amount of energy in a closed system is fixed. It can, however, be transferred from one object into another, and converted from one form to another.

Although we discuss energy production, you can't create new energy – only convert existing energy to a different usable form. A photovoltaic panel, for instance, taps into the Sun's radiant energy, converting it to usable electrical energy.

Likewise, the energy that we use doesn't disappear – it just changes into other forms. Switch on your television and the heat, sound and light energy emanating from the set gradually leak back into the environment.

Throughout history, numerous inventors have attempted to design and build perpetual motion machines that would give out more energy than was put in, but conservation of energy has made such inventions impossible – at least thus far!



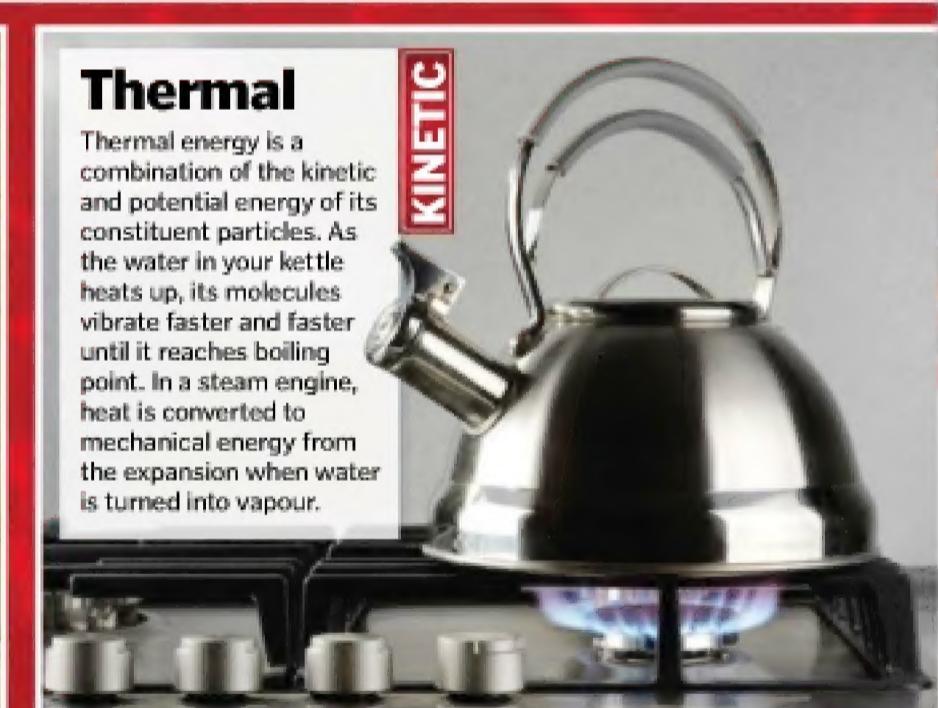
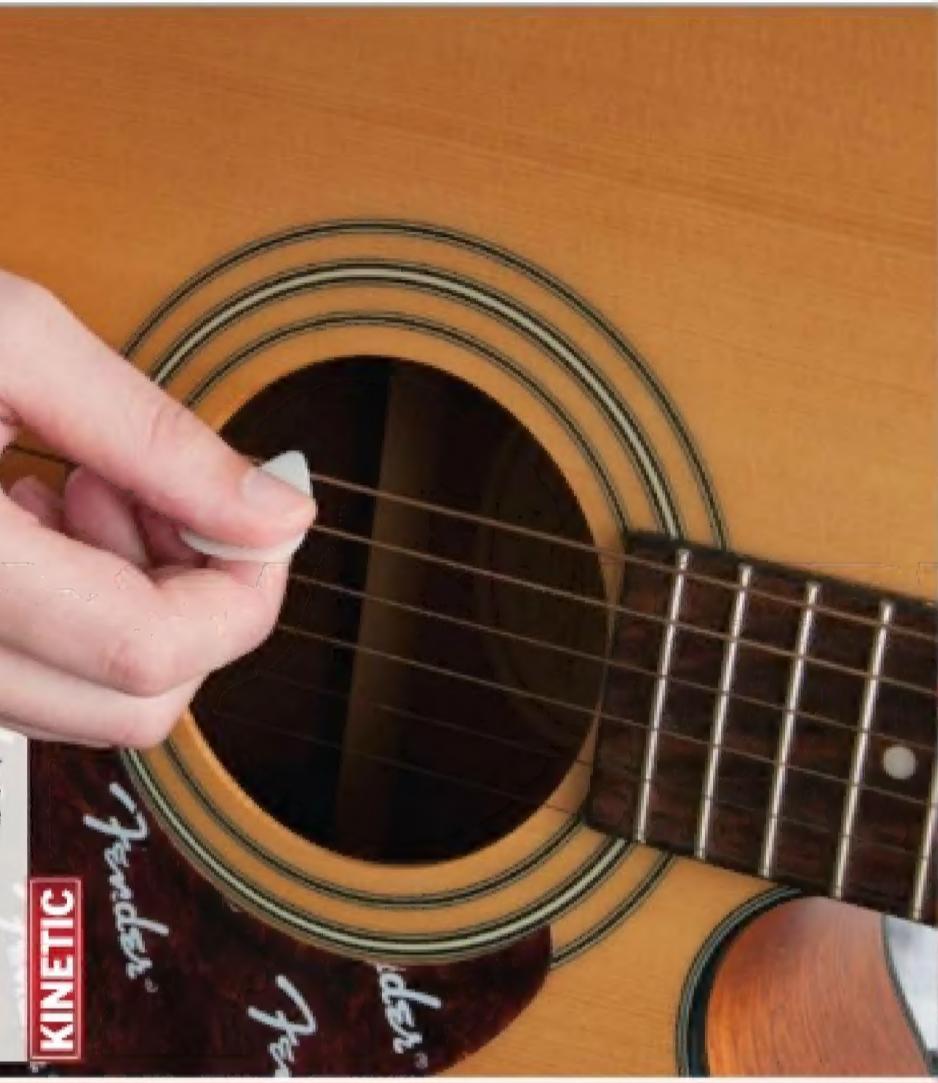
"Potential energy has its roots in the force acting between two objects and the distance between them"

POTENTIAL VS KINETIC ENERGY

The simplest way to classify energy is by dividing it into kinetic energy and potential energy. This distinction is, however, not enough to fully describe the different ways in which an object or a system can possess energy. Hence we have nine major forms of energy.

Kinetic energy is associated with motion. From an oxygen molecule through to a planet, the more mass an object has and the faster it moves, the greater its kinetic energy. The motion of different types of objects gives rise to different forms of kinetic energy.

Potential energy has its roots in the force acting between two objects and the distance between them. For example, the potential energy of a rock on top of a hill comes from the gravitational force between Earth and the rock. The more massive the rock, and the greater its height, the bigger its potential energy. Different forces give rise to potential energy under different names, as we see here.

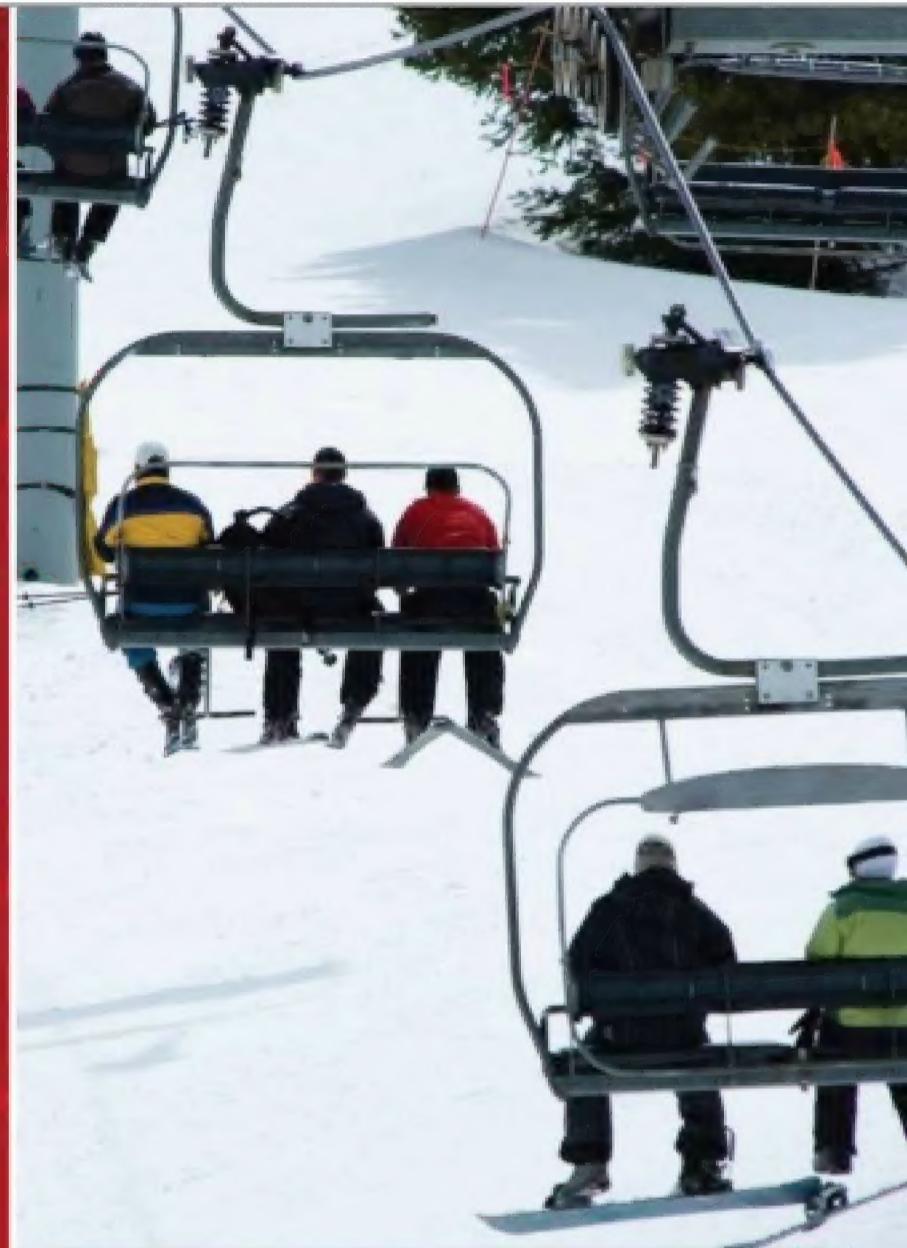
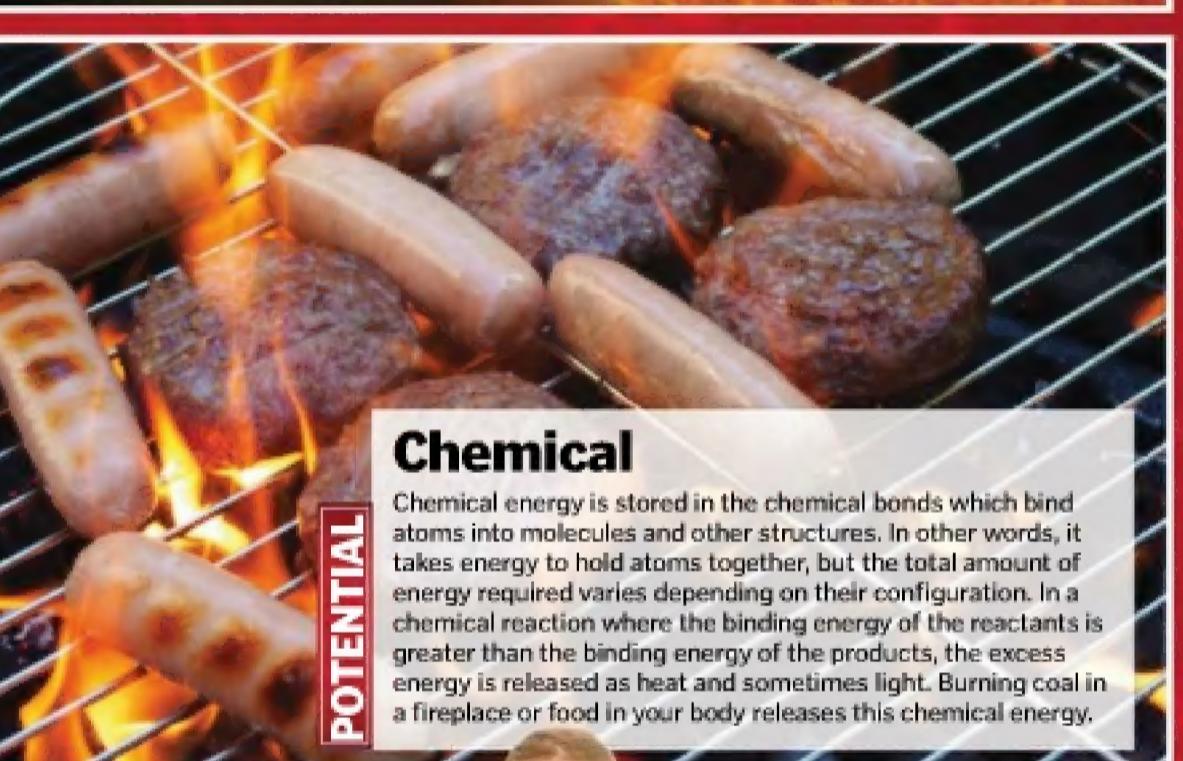


RECORD BREAKERS
WATER INTO WATTS

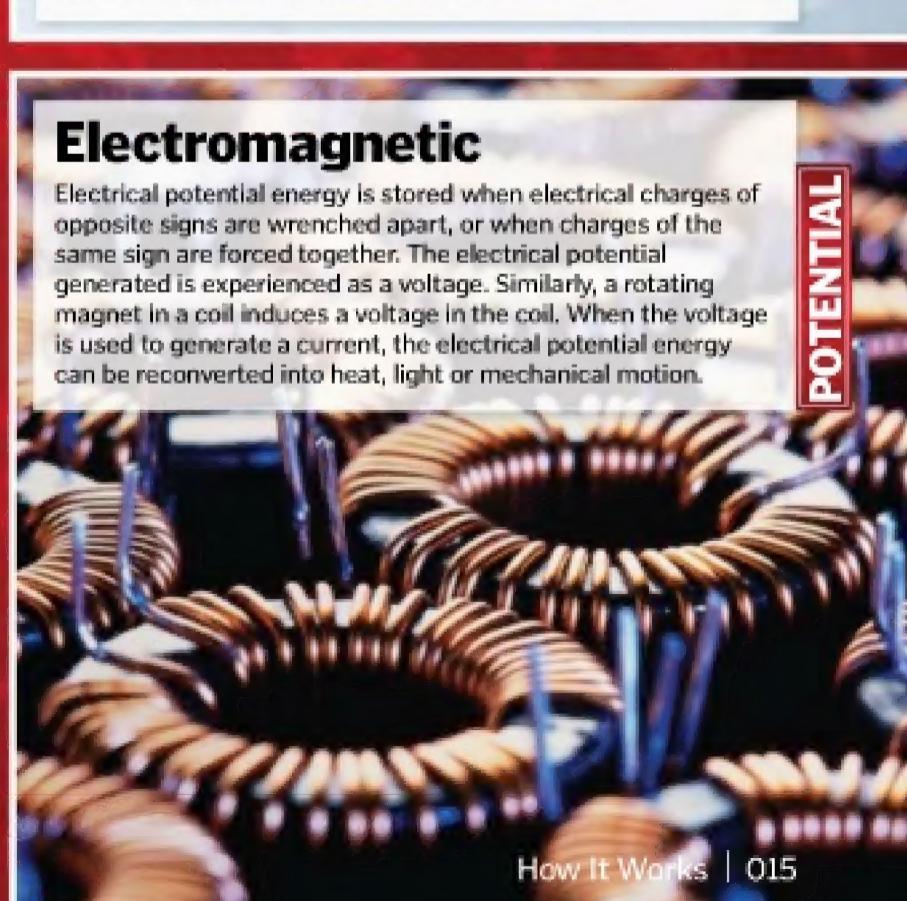
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DID YOU KNOW? On average, a US inhabitant uses over ten times as much energy than someone living in India

MOST PRODUCTIVE POWER STATION
The Itaipu hydroelectric dam between Brazil and Paraguay generates more energy than any other facility: over 98TWh. Water flows through it at up to 62,000 cubic metres (2.2 million cubic feet) per second.



Gravitational
Gravitational energy stems from the gravitational field around our planet (and other bodies). It arises, for example, when a skier rides a ski lift up a mountain slope. The higher the skier travels, the more potential energy is stored up. Once they set off down the slope, this stored energy is transformed into kinetic energy as they speed up down the slope.



"The simple act of making a piece of toast requires mastery of a large number of energy transformations"

**STRANGE
BUT TRUE
JOULE MAKER**

Which phenomenon releases the most energy?
A A human sneeze B A hurricane C An atom bomb



Answer:
A hurricane can release up to 10^{19} joules of energy in a day – a million times as much as an atom bomb like the one dropped on Hiroshima. Though sneezing expels droplets at high speed, the energy involved is tiny by comparison.

DID YOU KNOW? The tips of a spinning wind turbine can travel as fast as 290km/h (180mph)

HOW IS ENERGY TRANSFERRED?

Next time you take a hot shower, drive to work or plug in a laptop, spare a thought for the science that brings energy on demand into your home.

Energy transfers from one form to another occur around us all the time, but manipulating energy efficiently into useful forms is fundamental to modern life. Different uses require different forms of energy – a fan, for instance, requires motion energy, while thermal energy is essential for frying eggs.

The simple act of making a piece of toast requires mastery of a large number of energy transformations. In all likelihood, the energy that powers your toaster started off its journey as coal or gas. First, these fuels are burned, releasing the energy stored in their chemical bonds as heat (thermal energy), used to boil water. The resulting high-pressure steam spins a turbine, connected to a generator which converts the motion energy into electric energy. When you switch on your toaster, an electric current runs through the toaster's filaments and the electrical energy is converted into thermal energy once again.

Energy transfers also allow us to store energy for future use – for example, when charging a laptop battery or winding up a clock.

Rocket energy explained

Launching the Space Shuttle required a lot of energy, but where did it all go?

External tank

The external tank contains 720,000kg (1.6mn lb) of liquid oxygen and liquid hydrogen propellant to power the three main engines.

Heavyweight

At liftoff the shuttle weighs a hefty 2mn kg (4.5mn lb) – the majority of this weight is fuel.

Combustion

The boosters burn over 450,000kg (1mn lb) of solid fuel in just two minutes, before being discarded.

Heat

A lot of energy is transformed into heat and light, with temperatures inside the engines rising to 3,315°C (6,000°F).

Equator

Rockets launch eastwards and usually near the equator, taking advantage of the extra boost obtained from Earth's rotation.

Energy in a steam train

How a traditional steam train uses many kinds of energy

How energy transforms

1 Photosynthesis

Light energy is essential to plants, enabling them to convert carbon dioxide and water into glucose, thus turning radiant into chemical energy. Plants then use respiration to extract the glucose's chemical energy.



2 Filament light bulb

As electric current runs through the bulb's filament, electrical energy is changed into light energy. But traditional bulbs convert only ten per cent of incoming energy into visible light – the rest is wasted as heat.



3 Digestion

Your stomach breaks down your food to access the chemical energy stored inside sugars, fats and carbohydrates. Your muscles convert this energy into movement, generating thermal energy in the process.



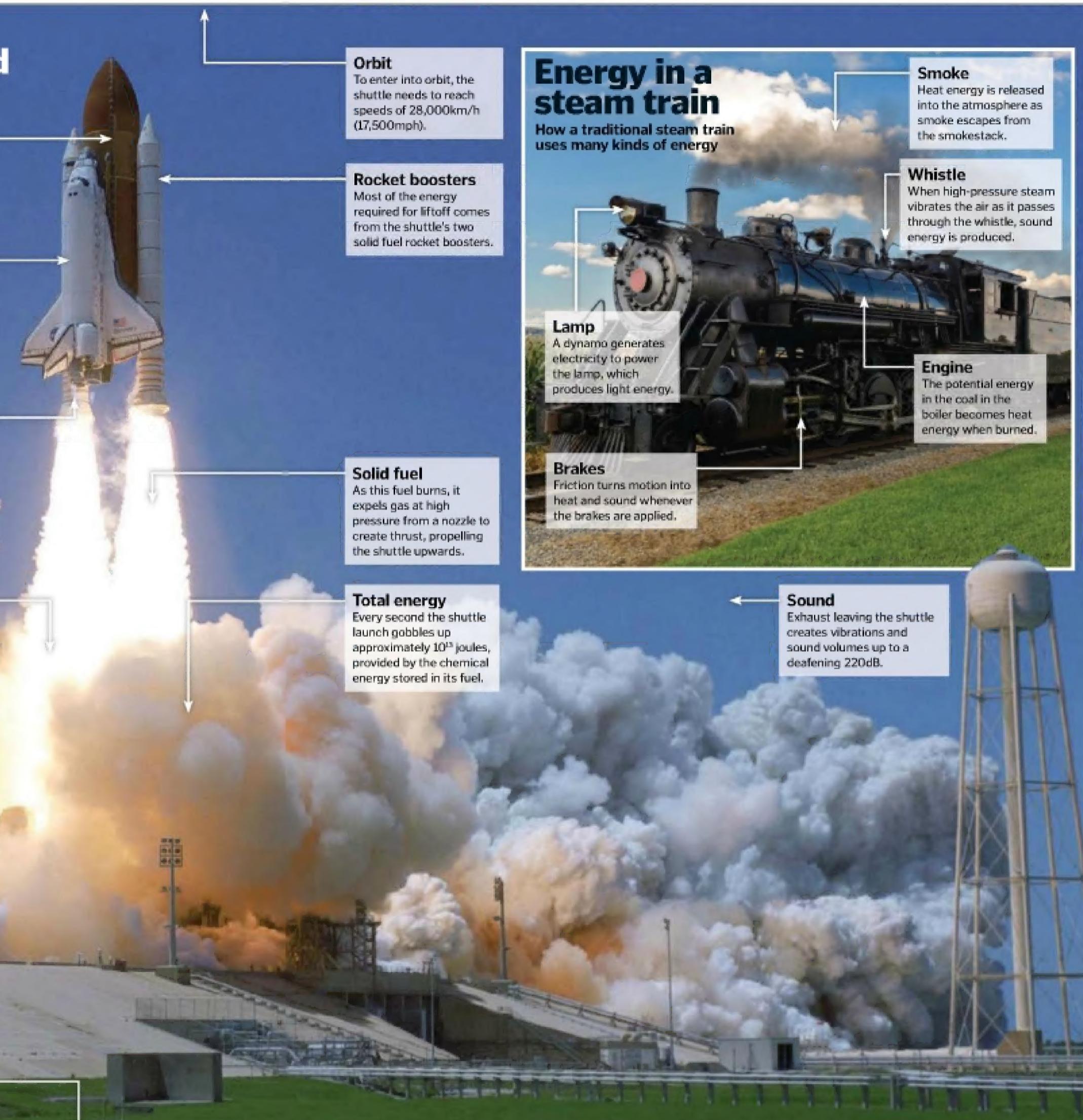
4 Tennis

Whacking a tennis ball causes the ball to travel in the direction of the racket, absorbing energy from the player's arm as well as the energy imparted onto the ball by your opponent's last shot.



5 Speaker

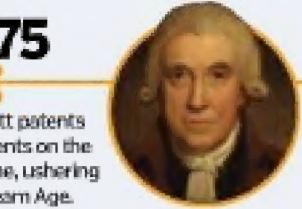
Inside a speaker, pulses of electrical energy running through an electromagnet change its magnetic field. This causes a permanent magnet to vibrate back and forth emitting sound energy.



"Nuclear fusion – the process that powers the Sun – could one day be a source of unlimited clean energy"

KEY DATES

ENERGY OVER TIME


1775
1830s
 James Watt patents improvements on the steam engine, ushering in the Steam Age.

1848
 The first modern oil well is drilled in Azerbaijan. By the early 1900s it accounts for half of global production.

1945
 The US detonates the first nuclear bomb, creating a blast equal to about 20 kilotons of TNT (or 84 terajoules).

2005
 The Kyoto Protocol comes into force, with 192 parties committed to limiting or reducing CO₂ emissions.

DID YOU KNOW? A person doing hard manual labour produces roughly enough energy to power a 100W light bulb

GOING GREEN

At any given moment, mankind is using roughly 15 terawatts of power – enough to run around 3 trillion iPads. Humans across the globe consume a total of around 500 exajoules (ie 10¹⁸ joules) of energy each year, and are expected to use over 50 per cent more by 2040. But our energy use is shockingly inefficient: in the US alone, an estimated 58 per cent of energy is wasted, mostly as unwanted heat.

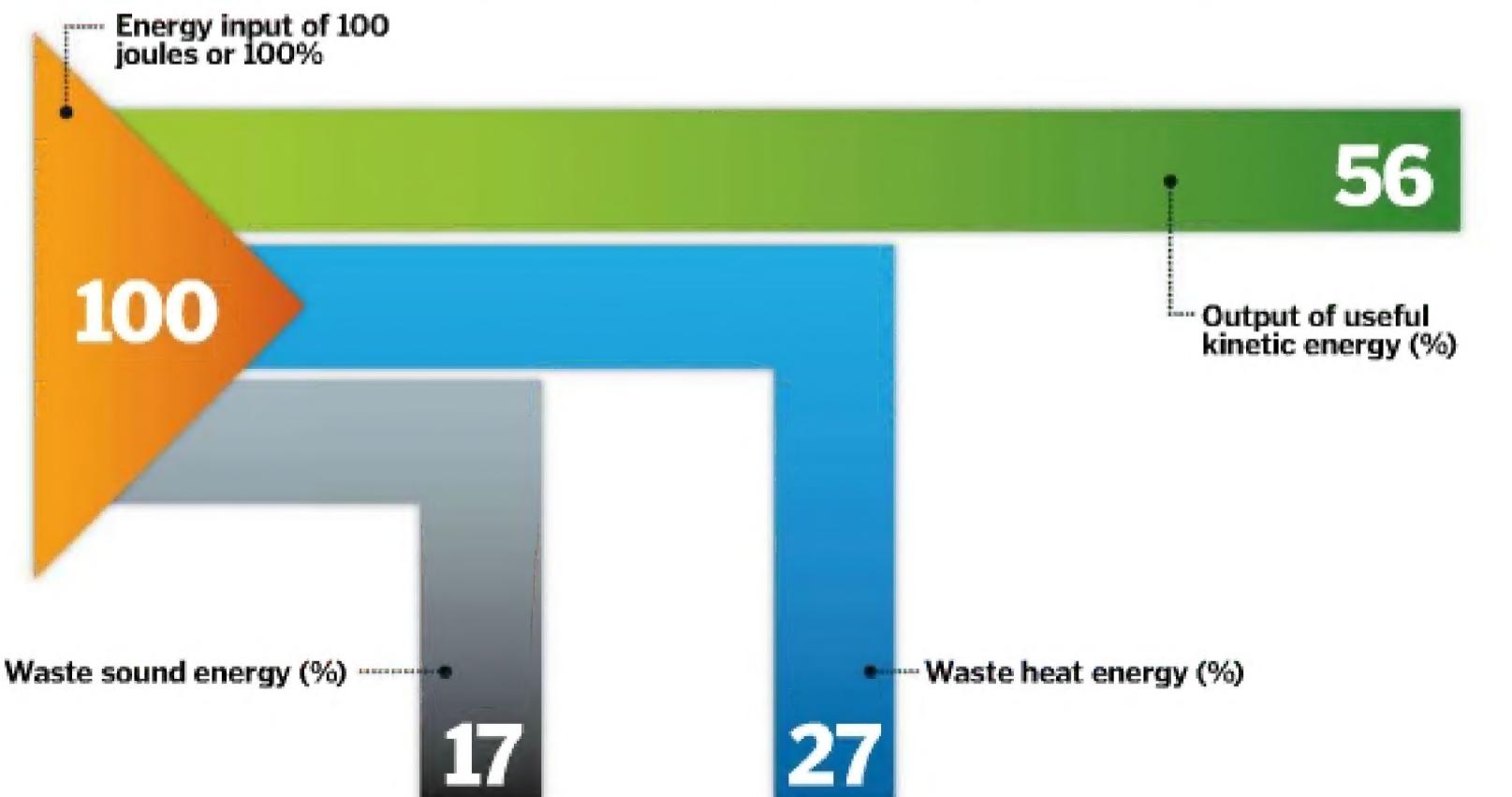
The majority of our energy currently comes from fossil fuels, but as reserves of oil, gas and coal grow short – and concerns about global warming grow ever-more pressing – renewable energy is on the rise. Renewable sources currently meet around 16 per cent of the world's energy needs, harnessing energy from the Sun, wind, tides, biomass or geothermal heat.

For wind, tidal or hydroelectric power this involves harvesting kinetic energy and transforming it into electric energy. A hydroelectric dam, for instance, takes advantage of the potential energy of the moving water which it traps. As water gushes through the dam, its kinetic energy is captured by spinning turbines. In turn these use magnets to convert motion energy into an electrical current.



Visualising efficiency

No energy transfer can be 100 per cent efficient. This flow diagram illustrates the energy transfers at work inside an electric motor. With an energy input of 100 joules, the motor turns 56 joules into usable kinetic energy – in other words, it has an efficiency of 56 per cent. The remaining energy is wasted as sound and heat. This information allows engineers to pinpoint which parts of a process can be improved to make efficiency gains.



Inside the ASDEX Upgrade

Fusion Reactor (Axially Symmetric Divertor Experiment) in Germany, where plasma for fusion reactions is made.

Fuelling the future

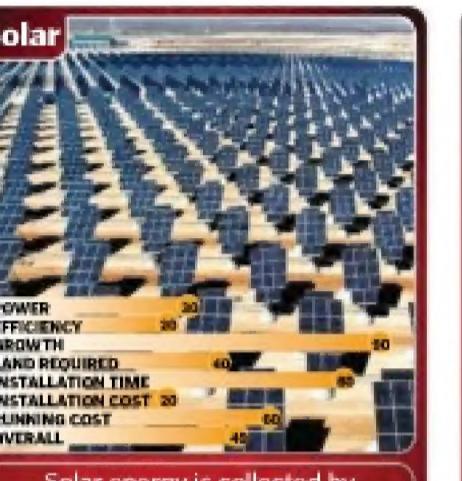
Meeting our planet's growing energy needs in a sustainable way is a tough challenge. Nuclear fusion – the process that powers the Sun – could one day be a source of practically unlimited, cheap, clean energy on Earth. The challenge, however, is creating the intense pressure and temperature conditions needed to coax hydrogen atoms into fusing and releasing some of their nuclear energy.

Cars of the future may fill up on biodiesel, ethanol or vegetable oil, or use electricity from a new source: hydrogen fuel cells. These combine hydrogen and oxygen to form water, exploiting the chemical energy released.

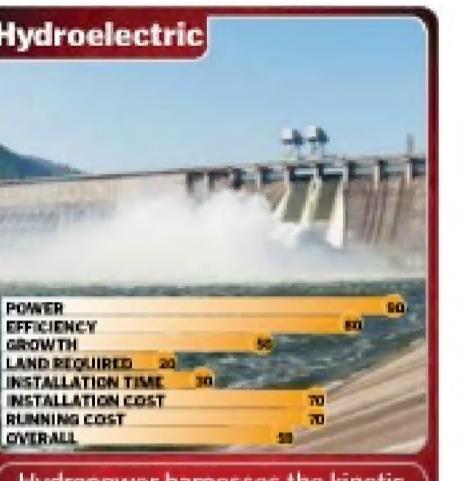


Renewables showdown

See how four major renewable energy sources square up



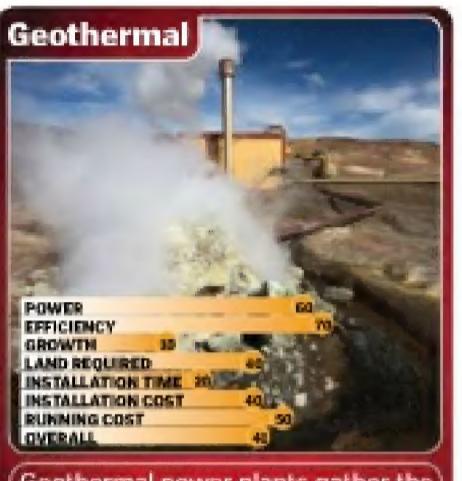
Solar energy is collected by photovoltaic cells, which transform light energy into electricity or thermal energy. Although the Sun provides limitless energy, the cells are quite inefficient and expensive.



Hydropower harnesses the kinetic energy of moving water and is the largest source of renewable energy. But building a hydropower station requires damming off a river, which can harm the local environment.



Wind turbines capture the kinetic energy of the wind and convert it into electricity. Relatively efficient and cheap to install, wind energy is a fast-growing business, though some think wind farms are ugly.



Geothermal power plants gather the heat produced at Earth's core. The catch is that this energy must find its own way to the surface, meaning geothermal power is limited to relatively few locations, eg Iceland.



Iceland's renewable energy jackpot

A geological stroke of luck allows Iceland to produce over 80 per cent of its energy (and 100 per cent of its electricity) from renewable sources. Straddling the Mid-Atlantic Ridge, a hub of tectonic plate activity, Iceland is dotted with over 200 volcanoes and some 600 hot springs, many of which spew out water at scalding temperatures of 250 degrees Celsius (482 degrees Fahrenheit). Exploiting this heat, geothermal energy meets 60 per cent of the country's energy needs. The hot water is used to warm houses, swimming pools and greenhouses directly, while geothermal plants also convert heat into electricity. Hydropower – made possible by the country's abundant rivers and waterfalls – makes up for a further 25 per cent of Iceland's energy requirement. This leaves 15 per cent of non-renewable energy, mostly used by oil-guzzling transport.

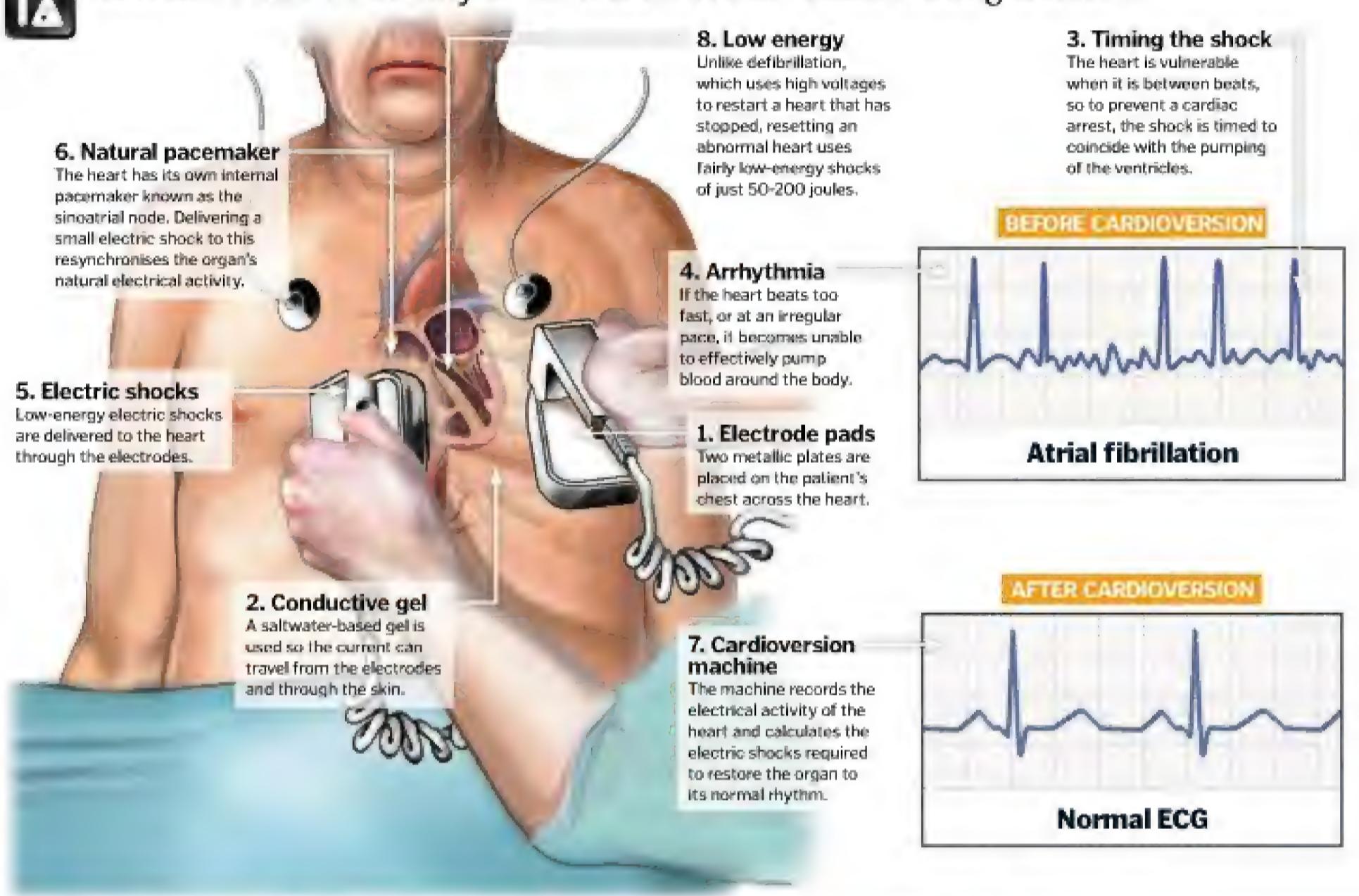


"The electric fields build up and electrons hurtle from the adhesive towards the tape"

Correcting heart rhythms



How can a little electricity be used to fix a heart that's beating off-kilter?

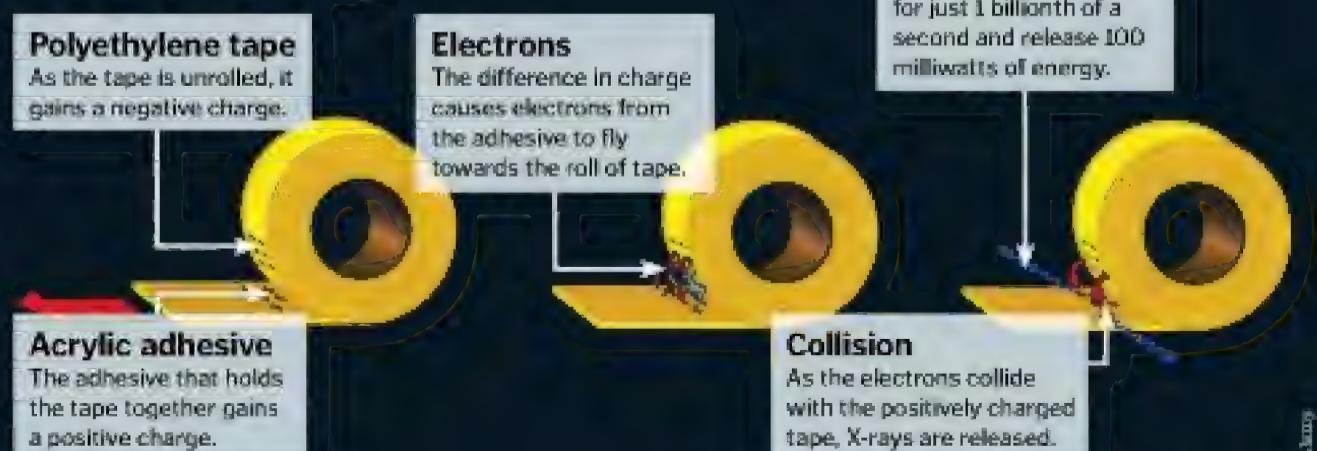


X-ray tape unravelled

Peeling sticky tape off the roll in a vacuum chamber releases X-rays powerful enough to image a human finger

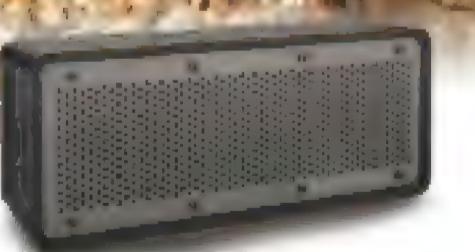


Occasionally when two surfaces move against one another, an electrical charge is generated and electromagnetic radiation – in the form of light, or X-rays – is released. This phenomenon is known as triboluminescence. As sticky tape is peeled from the roll, the acrylic adhesive becomes slightly positively charged, while the polyethylene tape becomes slightly negatively charged. The electric fields build up and electrons hurtle from the adhesive towards the tape, releasing X-rays on impact.



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"They make mistakes and mutate often, developing new genes as they adapt to their environment"

RECORD BREAKERS
TINY GIANT

0.75mm

MOST MASSIVE BACTERIUM

Thiomargarita namibiensis can grow to nearly a millimetre in length and is visible to the naked eye. It contains granules of sulphur, which scatter light, giving it a pearly glow.

DID YOU KNOW? Some bacteria can transfer genetic material to one another, including antibiotic resistance genes

Micro world of bacteria

There's much more to these tiny organisms than food poisoning and superbugs

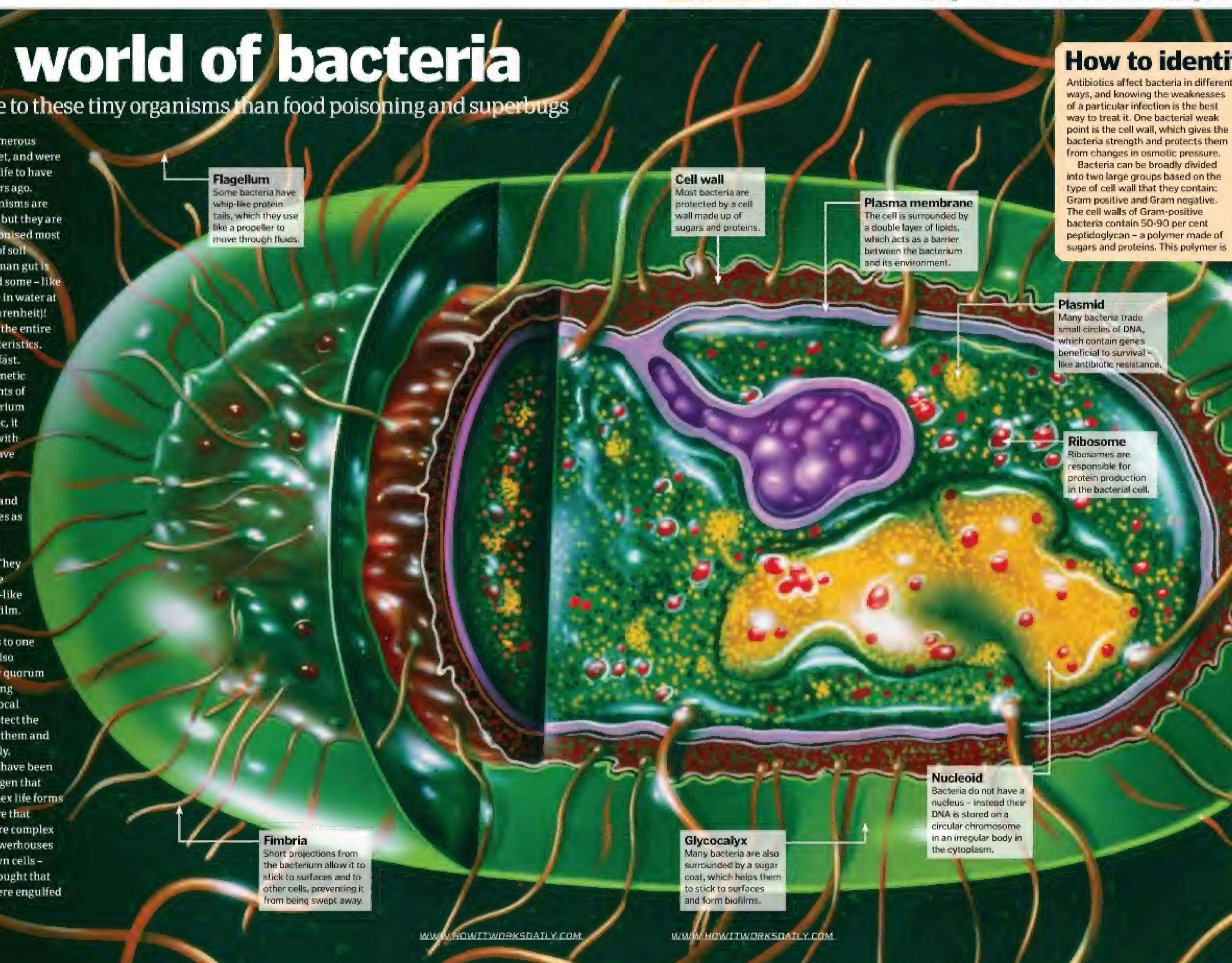
IA Bacteria are the most numerous living things on the planet, and were among the first forms of life to have evolved here, nearly 3.5 billion years ago.

These simple single-celled organisms are just fractions of a millimetre long, but they are incredibly adaptable and have colonised most environments. A single teaspoon of soil contains 1 billion bacteria, the human gut is colonised by 500-1,000 species and some – like *Thermus aquaticus* – can even live in water at 80 degrees Celsius (175 degrees Fahrenheit)!

Bacterial colonisation of almost the entire planet is a result of several characteristics. Firstly, they reproduce incredibly fast. Secondly, they are able to share genetic code by exchanging small fragments of DNA called plasmids – if one bacterium develops resistance to an antibiotic, it can share the genetic knowledge with its neighbours. Finally, bacteria have far fewer mechanisms to prevent errors being made in their DNA sequence, so they make mistakes and mutate often, developing new genes as they adapt to their environment.

Even though bacteria are single cells, they rarely live in isolation. They often attach to surfaces, and to one another, held together by a mucus-like carbohydrate matrix to form a biofilm. Within these bacterial colonies, individual cells make connections to one another to share nutrients. They also communicate with one another by quorum sensing; bacteria produce signalling molecules, which build up in the local environment, allowing them to detect the presence of other bacteria around them and change their behaviour accordingly.

Bacteria are not only thought to have been responsible for generating the oxygen that allowed the development of complex life forms on Earth, but scientists also believe that symbiotic bacteria gave rise to more complex organisms. Mitochondria – the powerhouses that generate energy inside our own cells – contain bacterial DNA, and it is thought that they originated as bacteria that were engulfed by their symbiotic companions.



How to identify bacteria

Antibiotics affect bacteria in different ways, and knowing the weaknesses of a particular infection is the best way to treat it. One bacterial weak point is the cell wall, which gives the bacteria strength and protects them from changes in osmotic pressure.

Bacteria can be broadly divided into two large groups based on the type of cell wall that they contain: Gram positive and Gram negative. The cell walls of Gram-positive bacteria contain 50-90 per cent peptidoglycan – a polymer made of sugars and proteins. This polymer is

woven into a mesh many layers thick, which sits on the outside of the plasma membrane. In contrast, the cell walls of Gram-negative bacteria contain less than ten per cent peptidoglycan, sandwiched between two plasma membranes.

The purple stain, Gentian Violet, sticks to the peptidoglycan in Gram-positive bacteria, but cannot bind to the sandwiched layer in Gram-negative bacteria. This allows the two cell wall types to be easily distinguished, and is often the first stage in bacterial identification.

What shape are they?

1 Spheres

Cocci are spherical bacteria. They can exist as individuals, in chains (like *streptococcus*), in groups that resemble berries (like *staphylococcus*), and even assembled into cubes of eight spheres.



2 Rods

Rod-shaped bacteria (bacilli) normally exist alone, but can combine to form chains and include well-known culprits like *E. coli* and *Salmonella*. The rod shape is maintained by a tough cell wall.



3 Comma

The most famous of these curved rod-shaped bacteria are those that cause cholera (ie *Vibrio cholerae*). Each has a single flagellum at one end, enabling it to swim through water.



4 Corkscrew

Spirilla are the least common type of bacteria and have a regular corkscrew shape. They often have flagella at either end to help propel them through fluids.





"If the tracheal opening is going to be a permanent feature then a piece of cartilage may be removed"

Tracheotomy surgery

Discover the science and tech behind this life-saving procedure



If the upper airway becomes blocked, either by facial trauma, cancer or inflammation, an alternative route must be found for air to enter the lungs.

Planned tracheotomies are performed under general anaesthesia or sedation. The neck is extended backwards to allow the surgeon to easily identify the structures in the throat and to make an accurate incision (see diagram). First, a vertical cut is made in the skin, below the tracheal cartilage, and the underlying muscle and blood vessels are carefully moved out of the way to expose the trachea.

The trachea is normally held open by C-shaped rings of cartilage, which prevent the airway from collapsing. A hole is made between the third and fourth rings, allowing the surgeon access to the airway without disrupting the cartilage supports. A tracheotomy tube is then inserted into the airway and secured to the neck. If the tracheal opening is going to be a permanent feature rather than temporary then a piece of cartilage may be removed to allow the tube to sit more comfortably.

The vocal cords sit just behind the tracheal cartilage, above the tracheotomy incision site, but in order to talk, air must be able to pass through the vocal cords to make them vibrate. Some tracheotomy tubes contain unidirectional valves, enabling the patient to breathe in through the tube and out through their mouth, which provides good air supply to the lungs, without hampering speech.

If the patient is unable to breathe unaided, a ventilator may be attached to mechanically move air in and out of the lungs. ☀

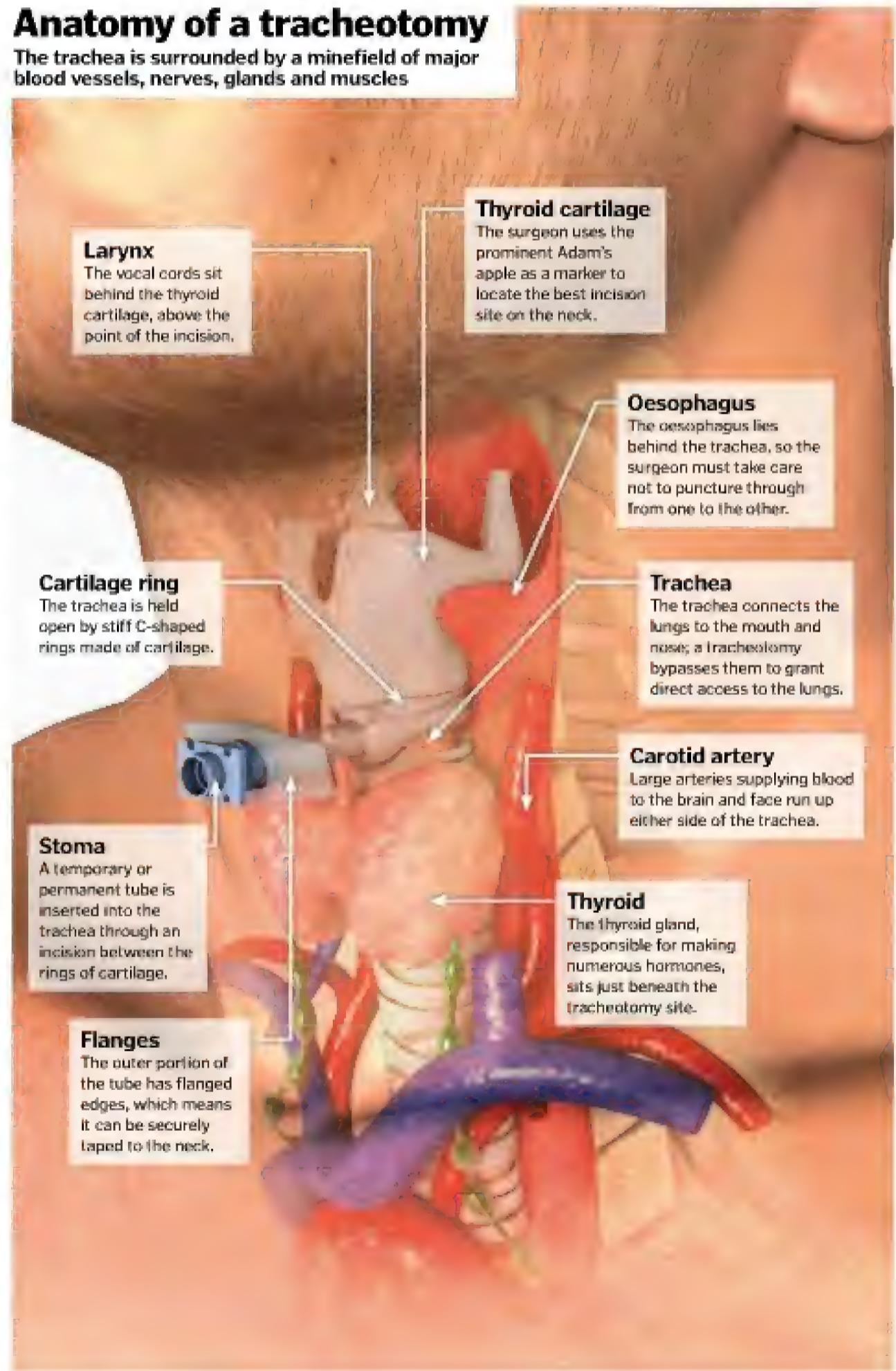
Have you got a pen?

A tracheotomy is a complex procedure, so in life-threatening, emergency situations a faster procedure – known as a cricothyrotomy (also called cricothyroidotomy) – may be performed. A higher incision is made just below the thyroid cartilage (Adam's apple) and then through the cricothyroid membrane, directly into the trachea.

It is possible to perform this procedure with a sharp instrument and any hollow tube, such as a straw or a ballpoint pen case. However, finding the correct location to make the incision is challenging, and without medical training there is great risk of damaging major blood vessels, the oesophagus or the vocal cords.

Anatomy of a tracheotomy

The trachea is surrounded by a minefield of major blood vessels, nerves, glands and muscles



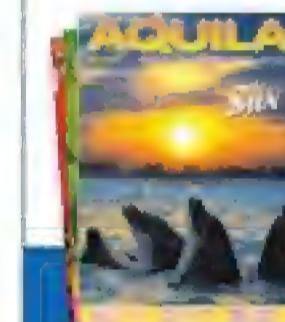
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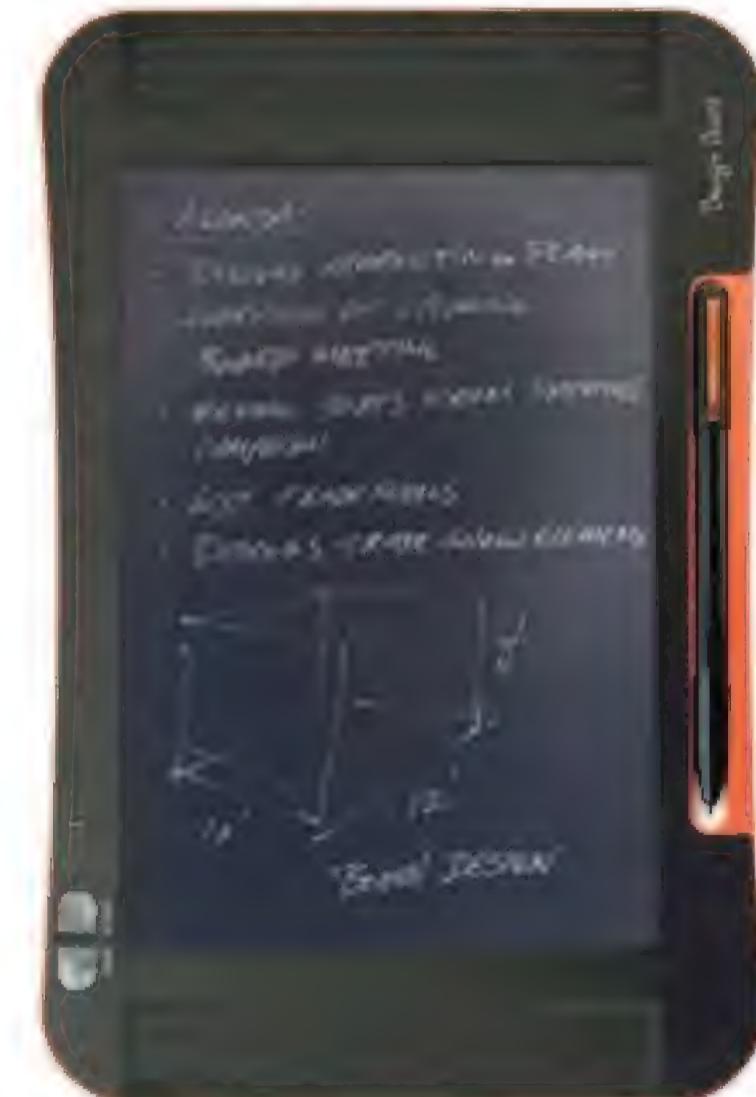


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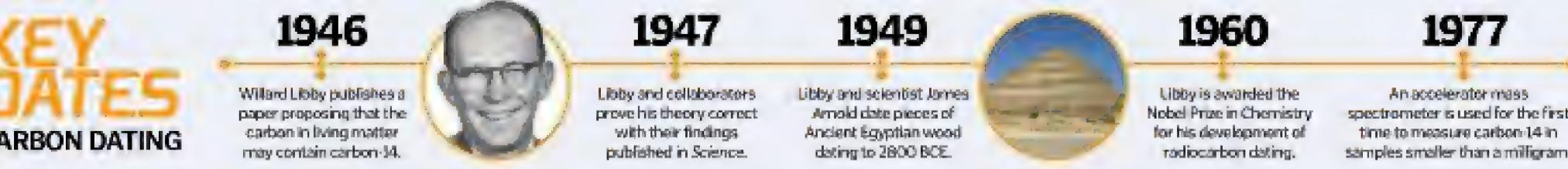
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"The radiocarbon dating process is a dependable method of measuring the age of organic remains"



How is carbon dating used to age remains?

Learn how science and technology are working hand in hand to pinpoint the age of ancient organisms, including humans

 Carbon dating is an ageing process that works by studying the decay of nitrogen in radiocarbon (carbon-14), with this substance present in every organic being. Carbon-14 is an intrinsic part of the biological carbon cycle on Earth, entering via green plants from the atmosphere and then passing up the food chain via animals. As such, while an organism is alive it will have a consistent level of carbon-14 stored in its cells.

Once an organism dies, however, that level of carbon-14 begins to decrease – something that occurs very slowly as carbon-14 has a half-life of 5,730 years, give or take 40 years. As a result, by measuring the radiocarbon, we can determine when the lifeform died (ie when the level of carbon-14 in its tissue stopped being topped up), though only to around 60,000 years ago.

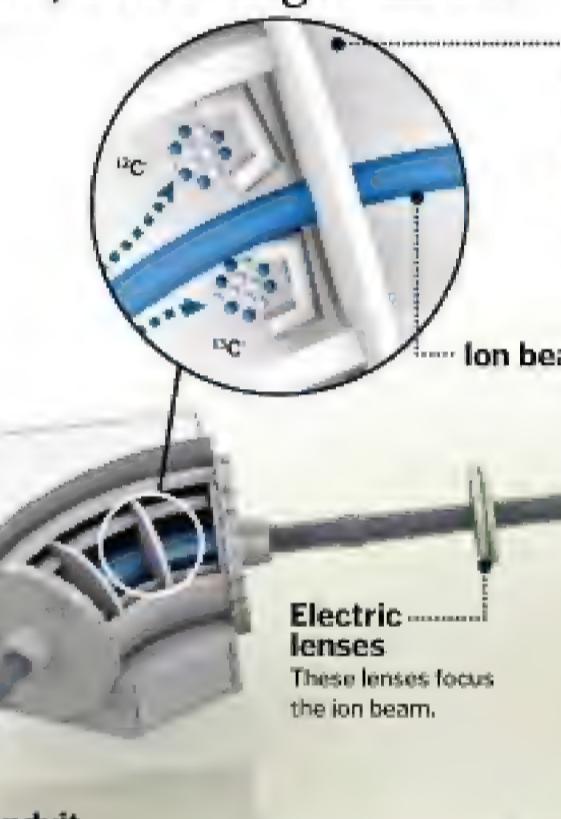
Ion preaccelerator

This helps to direct the carbon ions.



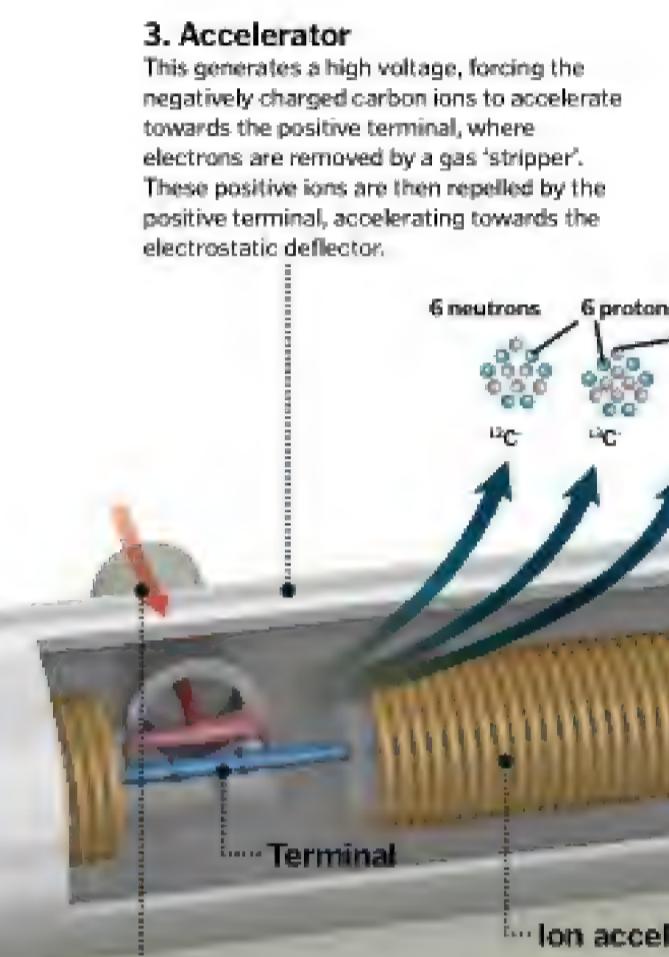
1. Ionisation

The sample is ionised, which is achieved by electron bombardment. For this, caesium (Cs) is used, which donates its electrons to the sample and creates negatively charged carbon ions. The result of such physical phenomenon is plasma that is induced by the conduit.



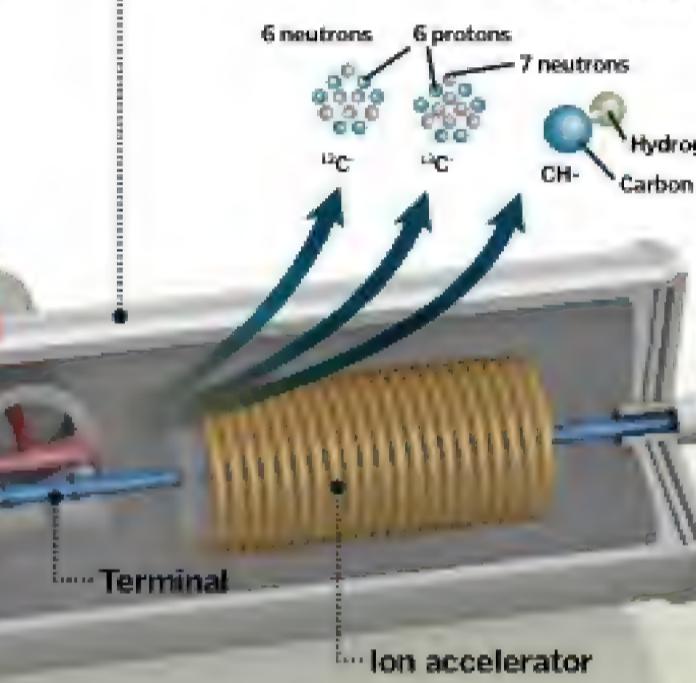
2. Magnetic deflector

This is the first separation of ions, where most of the unwanted isotopes, such as carbon-12 and carbon-13, are deflected to the sides of the accelerator. Carbon-14 ions and carbon hydrogen molecules (eg methane and methylene) are undeflected and travel on towards the accelerator.



3. Accelerator

This generates a high voltage, forcing the negatively charged carbon ions to accelerate towards the positive terminal, where electrons are removed by a gas 'stripper'. These positive ions are then repelled by the positive terminal, accelerating towards the electrostatic deflector.



4. Electrostatic deflector

This device creates an electrostatic field that deflects ions with a lower positive charge. Carbon atoms with higher positive charge, meanwhile, continue through the conduit.



5. Magnetic analyser

Ions with positive electrons (3^+) enter the magnetised field of the magnetic analyser. The carbon isotopes are deflected at different angles because of their varying masses. The ions of ^{14}C continue to the detector.

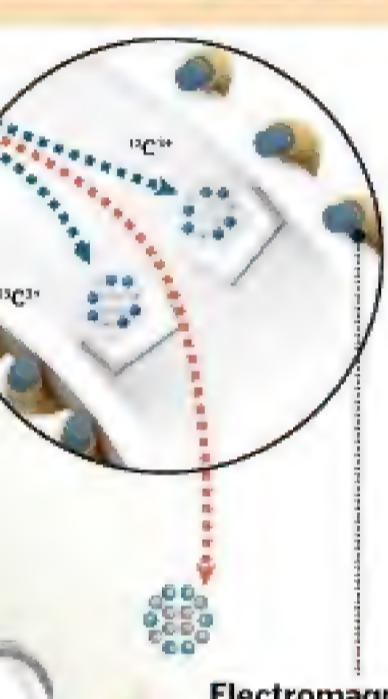


Sample size



The Turin Shroud

Three universities were chosen to date the ancient linen Turin Shroud in 1988, believed by some to have covered Jesus after he was crucified, but carbon dating concluded it was a medieval forgery. The sample consisted of a seven-centimetre (2.8-inch) cut, divided into three parts. (This image shows the scale of the sample, but doesn't indicate the area of extraction.) However more recent research by the University of Padua, Italy, has put the shroud much older at around 33 BCE.



6. Detector

Carbon molecules generate a pulse when they collide against the silicon plates of the detector; this is proportional to the energy of the ion. The number and energy of the ions are processed by a computer and displayed in a spectrograph.

Five alternative methods used to date artefacts

1. Dendrochronology

The technical name for dating tree rings. Every tree produces a ring per year, with the thickness varying according to climatic conditions. This method is very accurate, but is only useful for ageing up to 10,000 years back.

2. Rehydroxylation

Commonly used to date ceramic wares, this technique enables us to measure the amount of water that the clay elements have absorbed since they were fired to reveal fairly accurately when they were made.

3. Potassium-argon

Like carbon-14, it's based on radioactive decay, but in the potassium-40 isotope. It can date rocks that are millions of years old, but due to the long half-life of potassium-40, it's not generally used for samples older than 100,000 years old.

4. Uranium-238

The form of radioactive dating depends on the decay of uranium-238. Materials that are billions of years old can be dated with this technique, offering the chance for speculation about the very origins of Earth.

5. Thermoluminescence

This method measures the radiation emitted by the crystalline structure of inorganic matter, the pattern of which is similar to that of carbon-14. One of the main drawbacks of thermoluminescence is the high error margin.



The firepower on the latest battleships is mind-boggling – we explore the technology transforming 21st-century naval warfare



If you thought that the golden age of naval combat came to an end 200 years ago, then clearly somebody forgot to tell the national navies of today, as a wave of state-of-the-art, armed-to-the-teeth battleships are currently emerging from shipbuilding yards with a singular aim in mind: total domination of the seas.

From the brand-new and brutal Type 45 destroyers being pushed out of British dockyards, through to the almost sci-fi Zumwalt-class battleships emerging in the USA, and on to the cruising carrier vessels sitting like small islands in Earth's oceans, battleships are being produced en masse and to a more advanced spec than ever before.

Far from the basic heavyweights of bygone centuries, required simply to go toe-to-toe with

each other in a deadly game of broadsides, today's warships need to take down a variety of threats, whether at sea, on land or in the air, and they need to do so at extreme range. As such, step onto a battleship (today – be it a frigate, destroyer or corvette – and you'll find an arsenal of insane weapons systems.

There are cannons that can fire over distances of 95 kilometres (60 miles) and deliver a guided smart munition to a target with pinpoint accuracy, as well as Gatling guns that can automatically track a target moving at hundreds of miles per hour and then fire explosive bullets at up to 1,100 metres (3,610 feet) per second to take it down.

Missile launch systems not only increase the vessel's stealth but are capable of launching a wide variety of city block-levelling missiles

directly into the heart of enemy encampments in minutes from a safe distance, while naval guns are capable of subjecting a target to continuous bombardment with high-explosive shells with controlled abandon. All this is but a taste of the weaponry being fitted to the most advanced 21st-century warships.

The heavy armament of vessels currently known no bounds, with even coastguard fleets, convoy vehicles and civilian support ships being outfitted with some form of military-grade offensive weaponry. Clearly, controlling the world's waters is not as old-fashioned as the history books would have us believe. In this feature we take a look at the various types of battleship taking to the seas and the weapon systems that are revolutionising not just naval combat but warfare in general.

The British Type 45 has a displacement of 8,000 tons and can carry a crew of around 190

DID YOU KNOW? A Zumwalt-class destroyer costs around £2.4bn (\$3.8bn) to build

Rules of engagement

The key stages and technology that decide the outcome of a modern naval battle

Threats

Modern battleships are designed to engage a number of threats, including high-speed jet aircraft, rival battleships and deep-sea submarines.

Defensive

If attacked, a battleship can deploy decoy systems like flares and countering anti-missile munitions, or directly engage incoming threats with smart autocannons.



Battleship types



1 Corvette

One of the smallest types, the corvette is a lightly armed and manoeuvrable vessel used for coastal operations. Stealth corvettes are now becoming popular too.



2 Frigate

Lightly armed, medium-sized ships generally used to protect other military or civilian vessels. Recently, frigates have been re-focused to take out submarines.



3 Destroyer

Large and heavily armed, destroyers are typically outfitted for anti-submarine, anti-aircraft and anti-surface warfare, and can remain at sea for months on end.



4 Cruiser

The cruiser is an armed-to-the-teeth multi-role vessel akin to a modern destroyer. While cruisers are still in use, they have largely been superseded now.



5 Carrier

Ocean-going leviathans, carriers are the largest battleship. Their primary role is as a seagoing airbase, launching combat aircraft, but they also come heavily armed.



"The Advanced Gun System can fire ten of these LRLAPs per minute from its stealth-designed turret"



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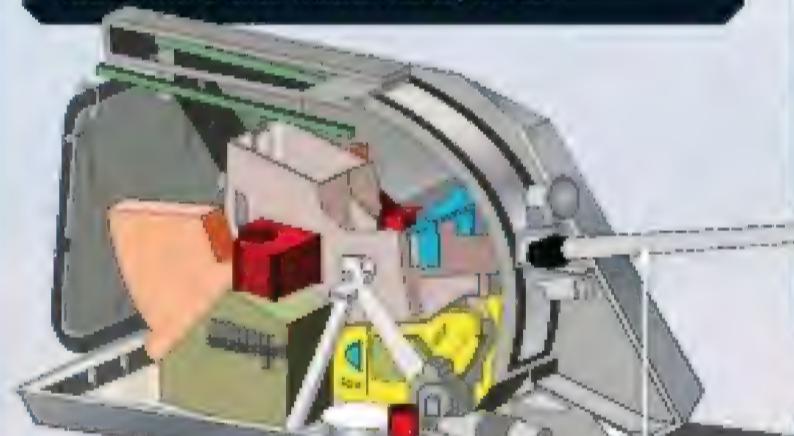
The Type 26 frigate is installed with the Phalanx close-in weapon system

Weapons in focus

We train our sights on four of the most advanced armaments aboard the latest battleships

Mk 110 naval gun

Capable of delivering automatic salvos of 220 57-millimetre (2.2-inch) Mk 295 Mod 0 ammunition - read: fragmenting high-explosive shells - each and every minute, the Mk 110 naval gun is quite simply a shell-slinging colossus. Stemming from one of the most long-lasting naval gun series of the last 100 years, the Mk 110 comes with a selection of hot features. These include the ability to fire both standard and smart munitions, a gun barrel-mounted radar for refined measuring of muzzle velocity, an instantaneous ability to switch between ammunition types, a stealth-oriented ballistic shield that protects the gun while allowing a full 360-degree traverse, plus a fully digital fire control system that enables the Mk 110 to respond to exact pointing orders and ammunition fuse selection milliseconds prior to firing. Indeed, the only thing that stops the Mk 110 from bombarding its target continuously is its shell capacity, which rests at 120 rounds with a three-minute reload process.



Turret

The MK 110's turret is capable of a full-circle sweep and contains the gun's firing systems. The turret allows the gun to elevate from -10° through to +77° and is protected with a ballistic shield to disguise it from radars.

Hoist

The MK 110's 57mm (2.2in) Mk 295 Mod 0 ammunition is delivered to the turret emplacement via a mechanical loading hoist. Ammunition is stacked 120 rounds deep and automatically fed into the firing chamber.

3
FIRE POWER

Advanced Gun System

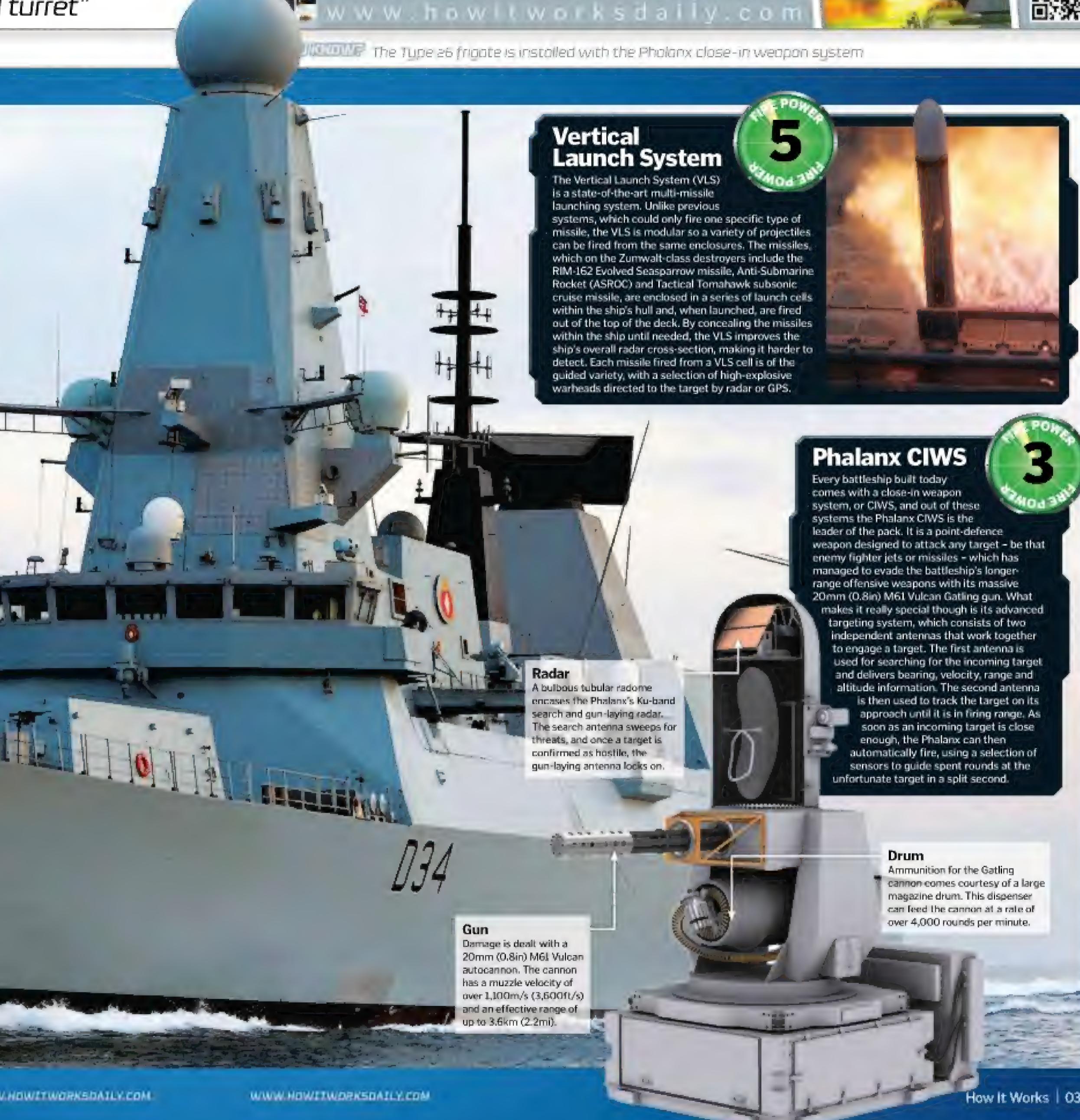
The Advanced Gun System (AGS) is a new naval gun from BAE Systems capable of firing precision munitions super-fast and at over-the-horizon ranges. What makes it special is that far from firing traditional unguided shells - as most naval guns have been designed for - it fires the Long Range Land Attack Projectile (LRLAP), a 155-millimetre (6.1-inch) precision guided artillery shell that, thanks to base bleed rocket assistance and an extended range fin glide trajectory, can travel over 105 kilometres (65 miles) to a target. What's more, it then has a circular error probable (ie accuracy) of only 50 metres (164 feet), making it incredibly precise even at great distance. Throw in the fact that the AGS can fire ten of these LRLAPs per minute from its stealth-designed turret and that it can fire traditional unguided munitions as well and it becomes clear why it's being incorporated into many of today's warships.



Barrel

The MK 110 has a single firing barrel with a progressive, 24-groove parabolic twist. The barrel's bore length is 3,990mm (157in), with the gun capable of firing 57mm (2.2in) conventional and smart munitions.

4
FIRE POWER



Vertical Launch System

The Vertical Launch System (VLS) is a state-of-the-art multi-missile launching system. Unlike previous systems, which could only fire one specific type of missile, the VLS is modular so a variety of projectiles can be fired from the same enclosures. The missiles, which on the Zumwalt-class destroyers include the RIM-162 Evolved Seaspark missile, Anti-Submarine Rocket (ASROC) and Tactical Tomahawk subsonic cruise missile, are enclosed in a series of launch cells within the ship's hull and, when launched, are fired out of the top of the deck. By concealing the missiles within the ship until needed, the VLS improves the ship's overall radar cross-section, making it harder to detect. Each missile fired from a VLS cell is of the guided variety, with a selection of high-explosive warheads directed to the target by radar or GPS.

5
FIRE POWER

Phalanx CIWS

Every battleship built today comes with a close-in weapon system, or CIWS, and out of these systems the Phalanx CIWS is the leader of the pack. It is a point-defence weapon designed to attack any target - be that enemy fighter jets or missiles - which has managed to evade the battleship's longer-range offensive weapons with its massive 20mm (0.8in) M61 Vulcan Gatling gun. What makes it really special though is its advanced targeting system, which consists of two independent antennas that work together to engage a target. The first antenna is used for searching for the incoming target and delivers bearing, velocity, range and altitude information. The second antenna is then used to track the target on its approach until it is in firing range. As soon as an incoming target is close enough, the Phalanx can then automatically fire, using a selection of sensors to guide spent rounds at the unfortunate target in a split second.

3
FIRE POWER

Drum

Ammunition for the Gatling gun comes courtesy of a large magazine drum. This dispenser can feed the cannon at a rate of over 4,000 rounds per minute.



"A typical car today can run for approximately 480 kilometres (300 miles) on one tank of fuel"

Plane mad

1 Using much bigger engines, a Boeing 747 can burn through about four litres (a gallon) of fuel a second. On a ten-hour flight it might use up to 150,000 litres (36,000 gallons).

Rise of biofuels

2 All diesel and petrol for road-going vehicles now contain some biofuel - up to five per cent ethanol in petrol and up to seven per cent biodiesel in diesel.

Dominant diesel

3 Although petrol is generally used to be the fuel of choice, more and more drivers are buying diesel cars because they achieve more miles per gallon (MPG) for the most part.

Keeping cool costs

4 Using air conditioning increases your fuel consumption as it's making your engine work harder. To make fuel go further, turn off all in-car gimmicks.

Premium price
5 Due to a growing shortage of crude oil from which petrol is derived, global prices of fuel have rocketed by nearly 70 per cent in the last six years, and only seem to be rising.

DID YOU KNOW? Over 30 billion litres (7.9 billion gallons) of fuel are sold on UK forecourts each year

Car fuel systems

Fuel is a vital component in getting a vehicle to move, but what happens after you've filled up your tank?

Carburetor For decades now, vehicles have been powered by combustion engines that rely on a constant feed of both air and fuel combining together to essentially explode.

As with a normal fire, oxygen is the catalyst for any explosion or ignition. The principle is the same inside a car's engine, where oxygen is mixed with fuel while simultaneously being fed into the cylinder heads where these controlled explosions force a series of pistons down, turning the crankshaft and helping to propel the vehicle along the road. Without these vital ingredients, the engine simply couldn't work.

When you fill up, fuel (either petrol or diesel) flows along a fuel line and down into a tank. The fuel is stored here in excess, but gradually empties as a pump provides a constant feed to the engine as soon as the car is fired up.

Once fuel leaves the tank, it is deposited via a rail into either a manifold on older systems, or - more likely today - straight into a cylinder head using direct fuel injection.

On older vehicles, a carburetor is used to adjust and measure the levels of air and fuel entering an engine, ensuring the right amount of both ingredients is supplied so that the vehicle runs efficiently. The job of carburetors is now also performed by fuel injectors in tandem with an engine control unit (ECU).

Fuel is burned in the engine, but some excess may be left over, which is simply taken back to the tank via a return line ready to be used again. A typical car today can run for approximately 480 kilometres (300 miles) on one tank of fuel - depending, of course, on conditions and the behaviour of the driver.

Carburetor up close

Although now superseded by fuel injection systems carburetors still play a vital role in classic cars as well as tools like chainsaws and lawnmowers

3. Jet

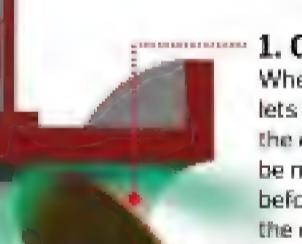
The jet allows a fine amount of fuel to be sprayed into the narrow venturi, where it can mix with air before travelling to the inlet manifold.

4. Venturi

This narrowing chamber is where air meets fuel in the carburetor. The ratio of air to fuel and the quantities of it passing into the engine can be adjusted via an idle mixture screw and an idle speed screw.

5. Throttle plate

Dictates when the petrol and air mixture enters an engine; in a car the throttle plate opens when the accelerator is pressed.



2. Float

Stops fuel from freely flowing into a carburetor, which can cause flooding. When up, no fuel flows, but during use the float is pushed down to allow fuel into the carburetor in spurts.

1. Choke plate

When opened, this lets clean air enter the carburetor to be mixed with fuel before being fed to the engine.

Engine control unit

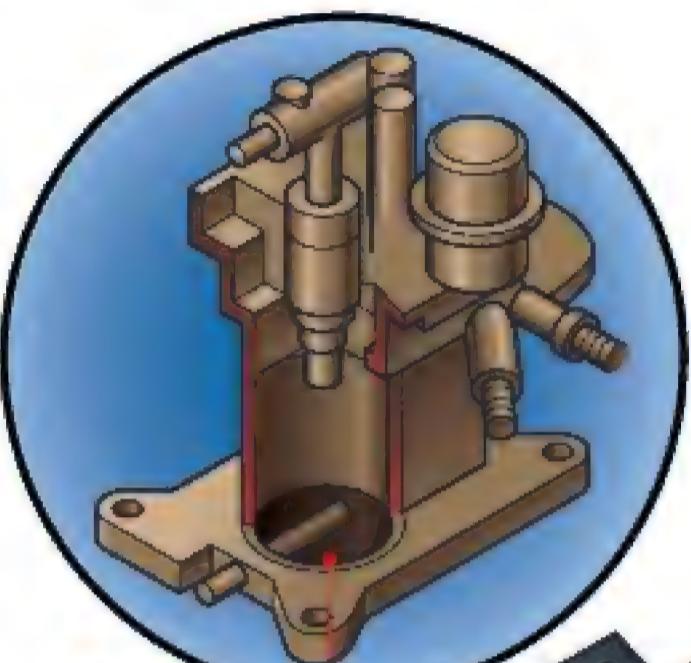
An engine control unit (ECU) ensures more fuel is let into the engine relative to the amount of air let in by the throttle valve. This is monitored by a variety of sensors.

Fuel rail

The fuel rail deposits fuel into individual injectors and sends any excess back to the tank via a return pipe.

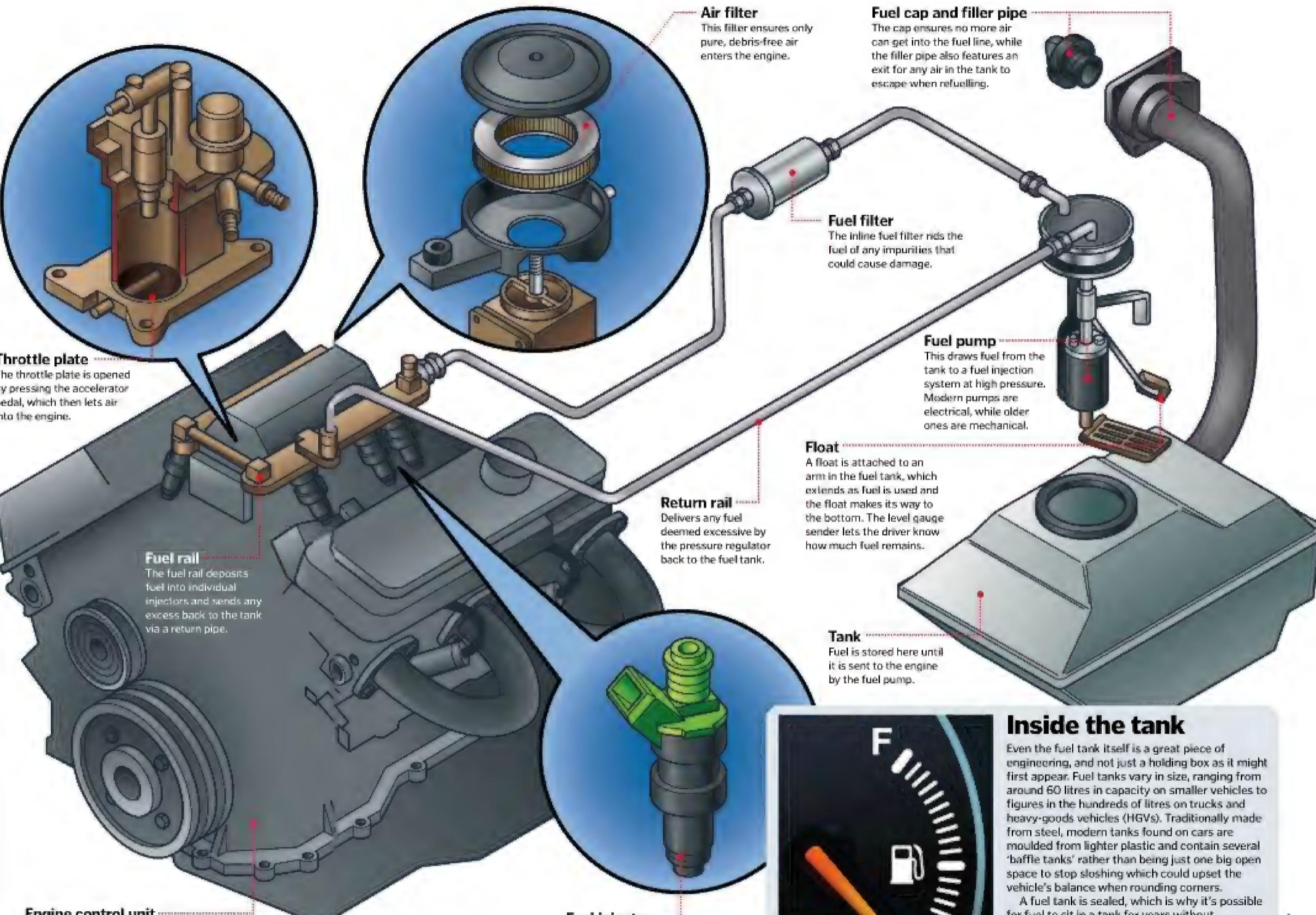
Throttle plate

The throttle plate is opened by pressing the accelerator pedal, which then lets air into the engine.



Fuel injector

These are used on modern cars to deposit fuel directly into the intake manifold, where the measured explosion takes place.



Inside the tank

Even the fuel tank itself is a great piece of engineering, and not just a holding box as it might first appear. Fuel tanks vary in size, ranging from around 60 litres in capacity on smaller vehicles to figures in the hundreds of litres on trucks and heavy-goods vehicles (HGVs). Traditionally made from steel, modern tanks found on cars are moulded from lighter plastic and contain several 'baffle tanks' rather than being just one big open space to stop sloshing which could upset the vehicle's balance when rounding corners.

A fuel tank is sealed, which is why it's possible for fuel to sit in a tank for years without excessively evaporating. Fuel is drawn from the tank using a pump, and a float on an arm allows a measurement to be taken of how much is left. With no fuel, the float sits at the bottom of the tank, fully extending the float arm, which sends a message to the dashboard to notify the driver that a visit to the petrol station is imperative.



"A watertight door will have strategically located locking points to provide compression of the seal"

What's inside a high-performance tyre?



Get to grips with how tyres keep a vehicle on the road

Tread

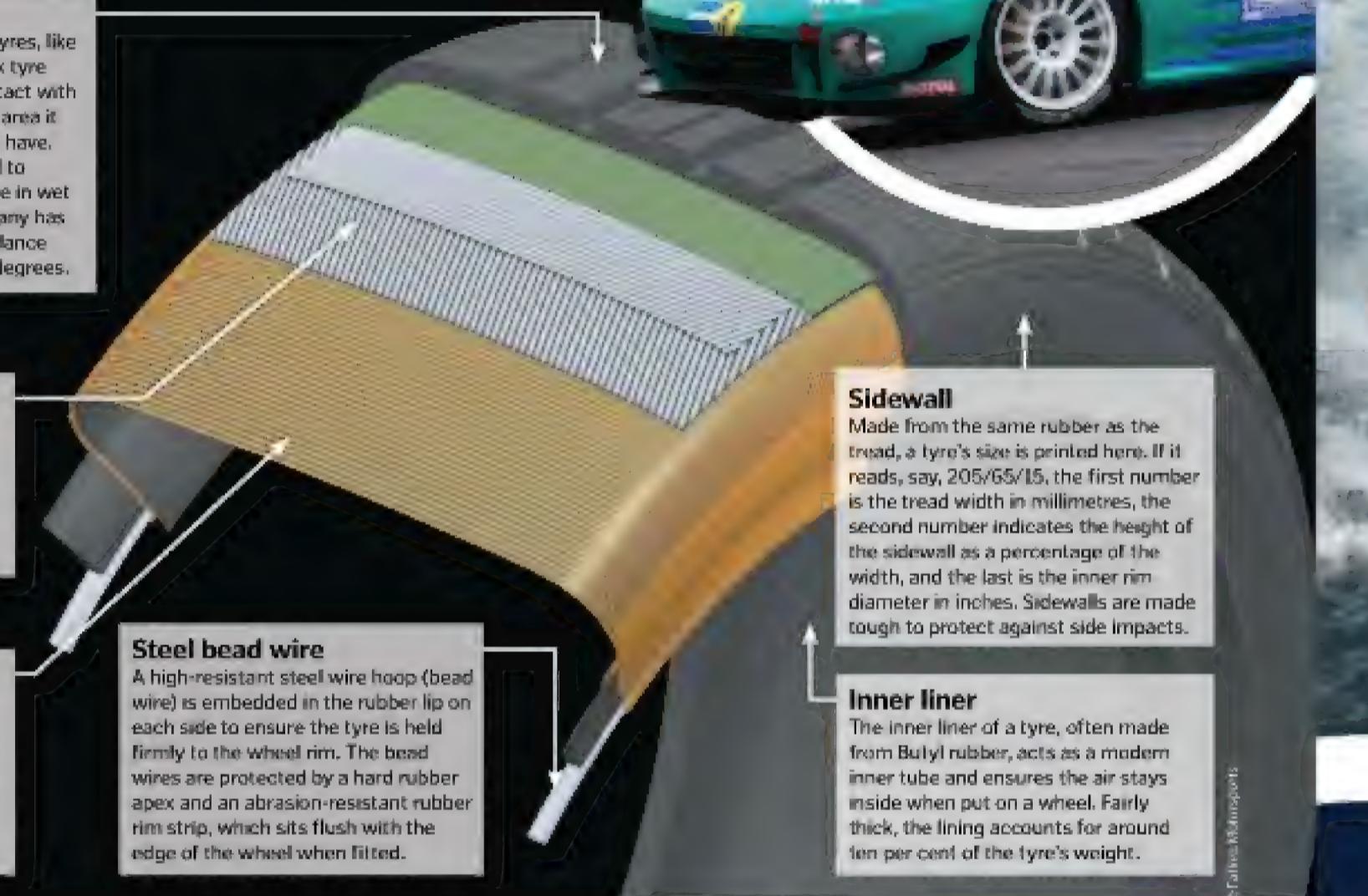
The rubber tread is where tyres, like this high-performance track tyre from Falken, come into contact with the road. The more surface area it has, the more grip a car will have. However a 'tread' is needed to disperse water from the tyre in wet conditions. Each tyre company has its own specifications to balance these elements to varying degrees.

Textile cap ply

The textile cap ply, or casing ply, is a parcelled fabric cord of many layers that forms a part of the substructure. This also helps reinforce the structure of the tyre and, along with the steel cord belt ply, protects against impacts.

Steel cord belt ply

Fine but durable steel belt plies help add to the textile cap ply on top by improving the tyre's resistance and reinforcement against the weight of a car. These plies are laid horizontally, ensuring a greater surface area is reinforced for directional stability.



Watertight doors

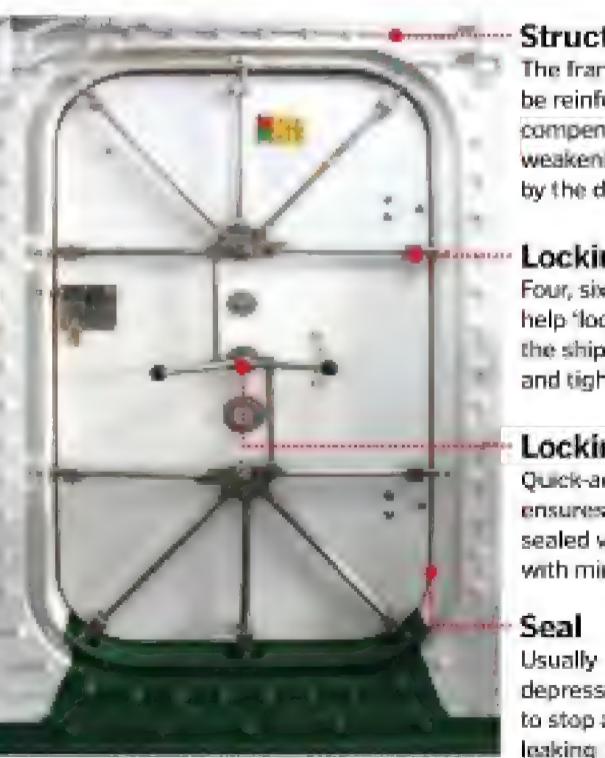
How do these special ship doors manage to hold their own against a flood of oncoming water?



Simple in design and yet vital in their role as an access solution in marine industries, watertight doors are able to stop water passing even under huge pressure.

Essential to their operation is a seal around the perimeter of the entrance being fully compressed and in contact with the 'knife edge' of the frame to prevent leakage. Equally, these doors must be incredibly strong and stiff (hence why they're usually made from steel) to

prevent any form of deformation or warping from the heavy loads brought by a head of water. To aid this, a watertight door will also have strategically located locking points to provide sufficient compression of the seal all over. These locking points are traditionally activated via a single central wheel/bar found in the middle of the door for ease of use. Watertight doors can either be hinged or sliding, square or radial, and they come in a number of different sizes.



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5 TOP FACTS: TYPE 45 HMS DARING



The ships primary conventional weapon is a BAE systems 4.5 inch mark 8.

For more information on the HMS Daring Type 45 Destroyer, please scan this QR Code with your smartphone.

TYPE 45 HMS DARING

Britain's six Type 45 'Daring Class' Destroyers are the most advanced escorts the nation has ever built. They are designed to shield a naval task force from air attack by using the Sea Viper missile system. Their Aster missiles can knock targets out of the sky over 70 miles away if required. The Type 45 destroyers are also capable of a range of other roles and will spend their commissions switching between them, often at short notice.

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Costly
The Type 45 is not cheap, costing over £1,050M per ship.

Replacing Type 42 Destroyers
It is suggested that, during an 'intensive attack', a single Type 45 could simultaneously track, engage and destroy more targets than five Type 42 Destroyers operating together.

Size
The Type 45 Destroyers are much larger than the Type 42 they replaced. Being 152.4 m in length, with a beam of 21.2 m and a draught of 7.4 m.

Accommodation
The Type 45s are the first Royal Navy ships to include gender neutral living spaces.



"Less than 25 of these bridges have ever been constructed – and only a few remain in use today"

The Widnes-Runcorn Transporter Bridge over the River Mersey, UK, was the largest ever built. It had a main span of 300 metres (984 feet) and two towers each 58 metres (190 feet) high. However it was demolished in 1961.

DID YOU KNOW? Only six transporter bridges remain in operation around the world, most of which are in Europe

Aerial transfer bridges

Learn how transporter bridges carry cargo and passengers across water

One of the biggest challenges in bridge building across busy rivers is allowing boats to navigate them freely.

Solutions have been invented in the form of a variety of movable bridges, with sections that retract, lift up or even sink to make room.

A rare example is the transporter bridge, or aerial transfer bridge, which uses a movable platform, or gondola, to carry loads from one bank to the other. There are very few examples worldwide – indeed, less than 25 of these bridges have ever been constructed – and only a few remain in use today.

The construction of transporter bridges varies. The Vizcaya Bridge in Spain has two pillars connected by a crossbeam and supported suspension cables, while the Tees Transporter Bridge (pictured) in the UK is a cantilevered design with two halves, each supported entirely by two towers at either end.

Despite the differences in their overall structure, transporter bridges all work using the same fundamental mechanics. The gondola is suspended below the bridge by a series of steel cables, which attach to an overhead trolley. The trolley sits on a track, which runs the length of the bridge, and a winch system is used to draw the platform and its cargo back and forth across the waterway.

The gondolas have a large carrying capacity and can often transport several hundred people or several vehicles at once. They also provide an advantage over traditional bridges in that they can take passengers directly from ground level. If the riverbanks are very low, a long approach road is required to get vehicles to the correct altitude to cross a normal bridge.

Engine room
An engine room supplies power to the winch used to move the gondola.

Anchor arm
The bridge is counterbalanced by two anchor arms that extend away from the cantilever arms.

Track
A track between the two towers allows the trolley to move back and forth along the bridge.

Cantilever arm
The bridge is made from two cantilevers, each supported by a pair of towers.

Anemometer
The gondola has equipment to detect wind speeds; if the wind reaches 56km/h (35mph) the bridge is closed for safety.

Gondola
Passengers travel across the bridge using a large moving platform.

Foundations
The bridge is supported by strong granite foundations buried deep beneath the ground.

Trolley
The platform is suspended below a trolley, which moves the gondola across in two and a half minutes.

At 259m (851ft) long, the Tees Transporter Bridge in Middlesbrough is one of the longest of its kind still in use

The science of cantilevers

The Tees Transporter Bridge in Middlesbrough is built using two cantilevers. The beams of a cantilever bridge are supported at only one end, and the entire load is transferred to support towers. Cantilever bridges are often made out of structural steel for its ability to resist stress, and crossbeams may also be included to distribute the load. The cantilever is supported by a steel or concrete tower, and is balanced by a second arm known as the anchor arm. The anchor arm is connected to the cantilever arm and extends in the opposite direction, providing a counterbalance to the unsupported end of the structure. The anchor arm is firmly linked to the ground by either a second tower or – in the case of the Tees Transporter Bridge – steel cables (see X-shaped structure on far left).

Cables
The gondola is attached to overhead rails by a network of steel cables.

Five bridges that move

1 Drawbridge

Drawbridges were one of the first types of movable bridge. Attached to rope or chain and a counterweight, they are raised and lowered by turning a crank, and function not just as a bridge over a moat or ditch but also as a dam.



2 Folding bridge

Folding bridges are made from several segments. As the bridge opens, the segments are pulled into a concave line by counterweights, forming a folded 'W' shape and allowing boats to pass underneath.



3 Bascule bridge

The arms of a bascule bridge, like London's Tower Bridge, swing up, so boats pass through the centre. They work in a similar manner to a seesaw, using a counterweight to move the arms upwards.



4 Tilt bridge

A tilt bridge has a curved deck, which rotates around a central axis. When a boat needs to pass, the bridge tilts upwards, transforming the walkway into an arch for the vessel to travel beneath.

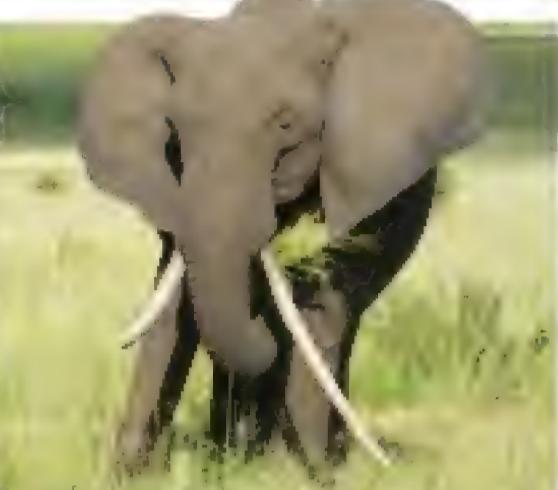


5 Submersible bridge

Instead of lifting up, a submersible bridge, like the Mytilene Chios Canal in Greece, has a net-like basket that sinks below the water to allow boats to pass. This removes no height restrictions imposed on the river traffic.



DID YOU KNOW? A single molar tooth from an elephant is the size of a house brick



NATURE'S GIANTS

Taller, heavier, stronger – these are wild animals at large



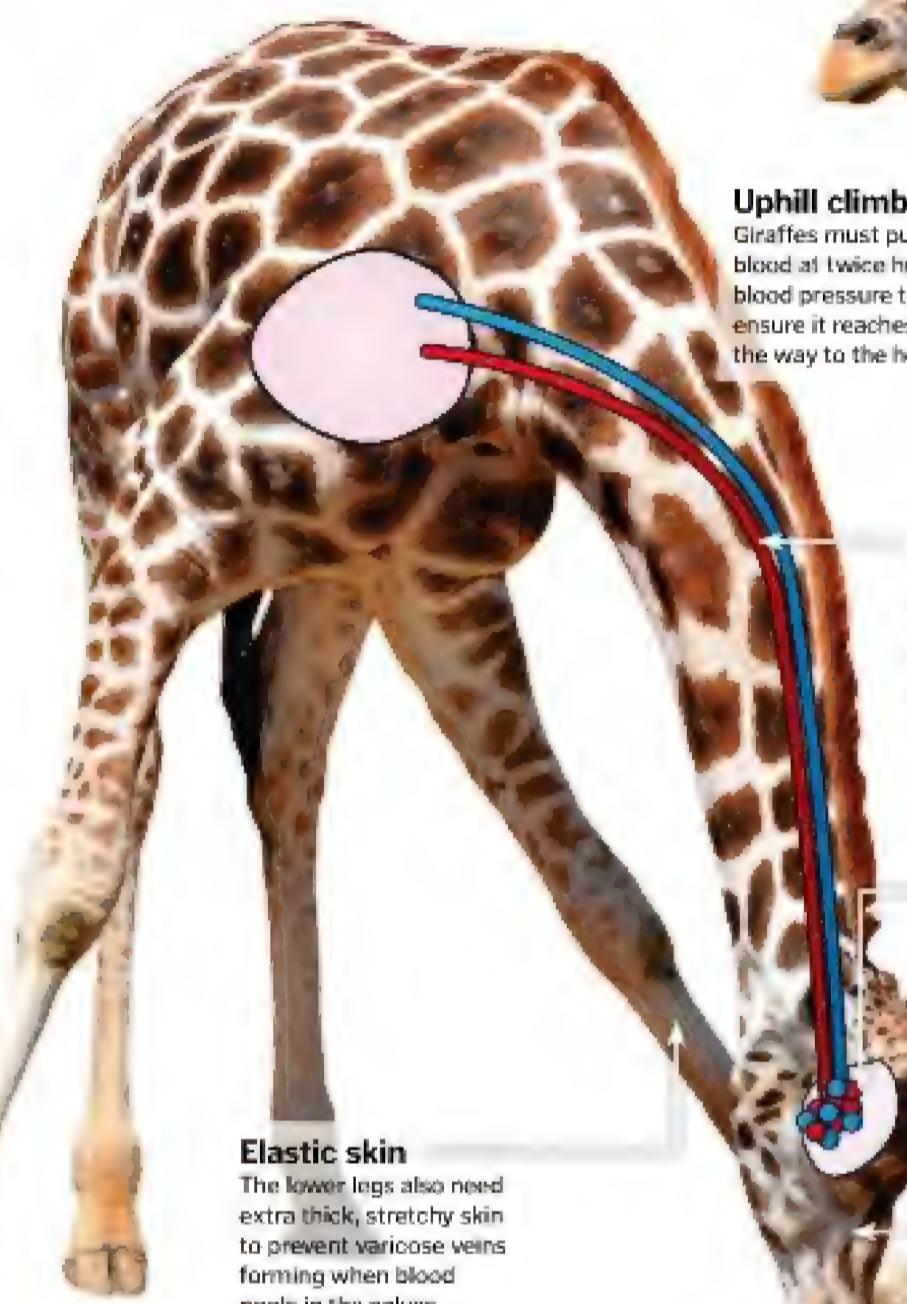
Bigger is better. That's not just an expression, it's an evolutionary phenomenon called Cope's rule: animals tend to evolve into bigger animals. Over millions of years dinosaurs went from small reptiles into ground-shaking giants. After they went extinct, mammals became the dominant land animals and they too inexorably evolved from mouse-like critters into oversized behemoths such as a six-metre (20-foot) sloth *Megatherium* and the 12-ton-plus, horse-like *Paraceratherium*. When the ice ages came, the largest species were wiped out and smaller ones took over and started growing once again. The giant animals that exist today are just the

latest swing of a pendulum that has been marking time over geological timescales. Natural selection drives species to evolve larger bodies for several reasons. Being huge obviously makes it harder for you to be eaten by predators, but this is only part of it. The fiercest rivals most animals face are other members of their own species. The biggest males will be the ones to control the largest territories and have access to breeding females. Darwin thought the giraffe's long neck evolved so that it could reach the leaves on the tallest branches, but recent research has suggested that it may actually be because winning 'necking' contests is how males establish dominance over each other.

Eventually every species will reach a limit to its size. During the Carboniferous period around 300 million years ago, insects and other invertebrates grew to enormous sizes. There were dragonflies with 75-centimetre (30-inch) wingspans and a millipede-like creature called *Arthropleura* over two metres (6.6 feet) long. But this was at a time when the oxygen concentration in the atmosphere was above 35 per cent, rather than the 21 per cent it is today. Eventually the oxygen level was so high that forests – and even swamps – caught fire with every lightning strike. As they burned, the oxygen in the air fell to much lower levels. Without sophisticated lungs and circulatory

Dizzy spells

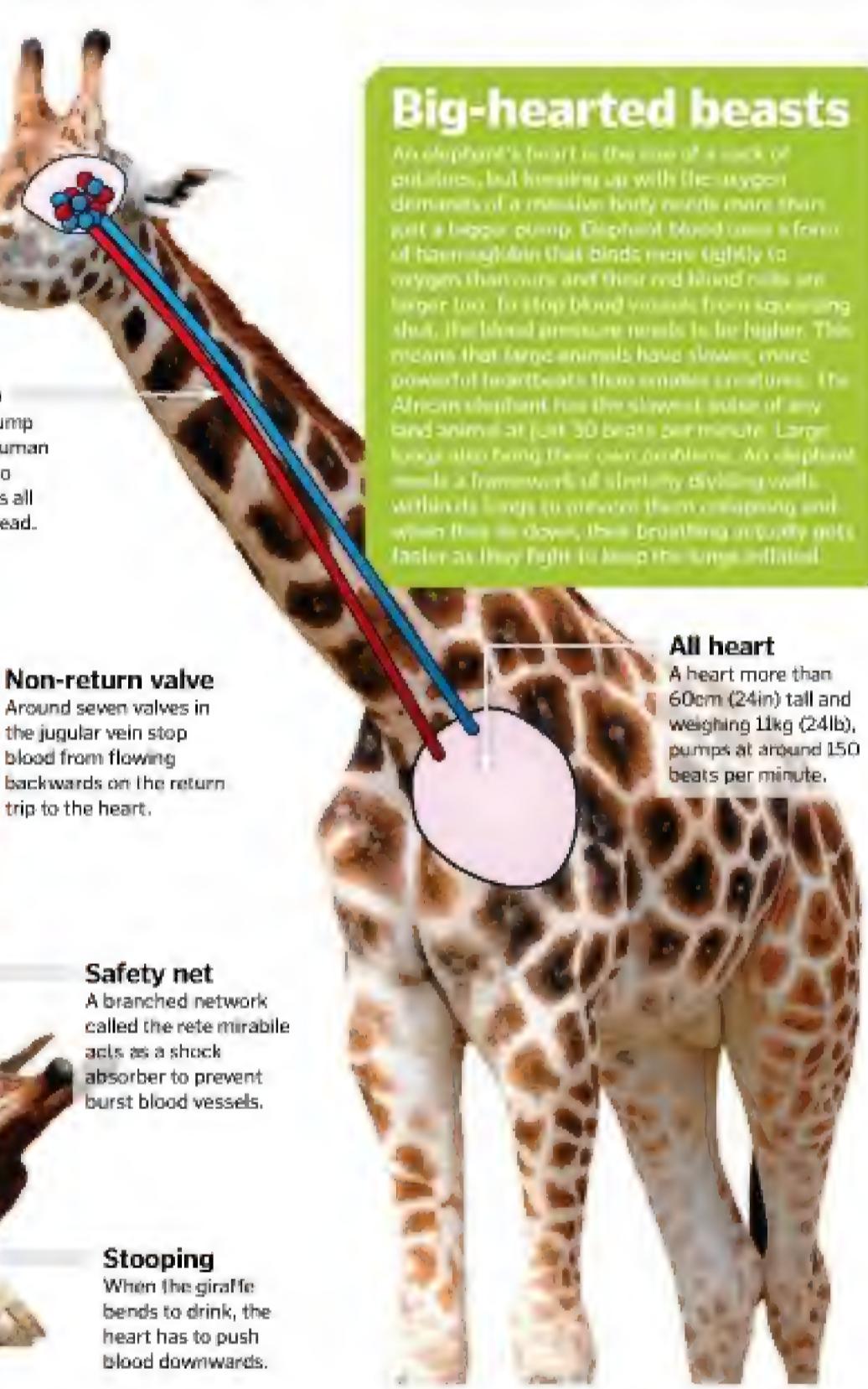
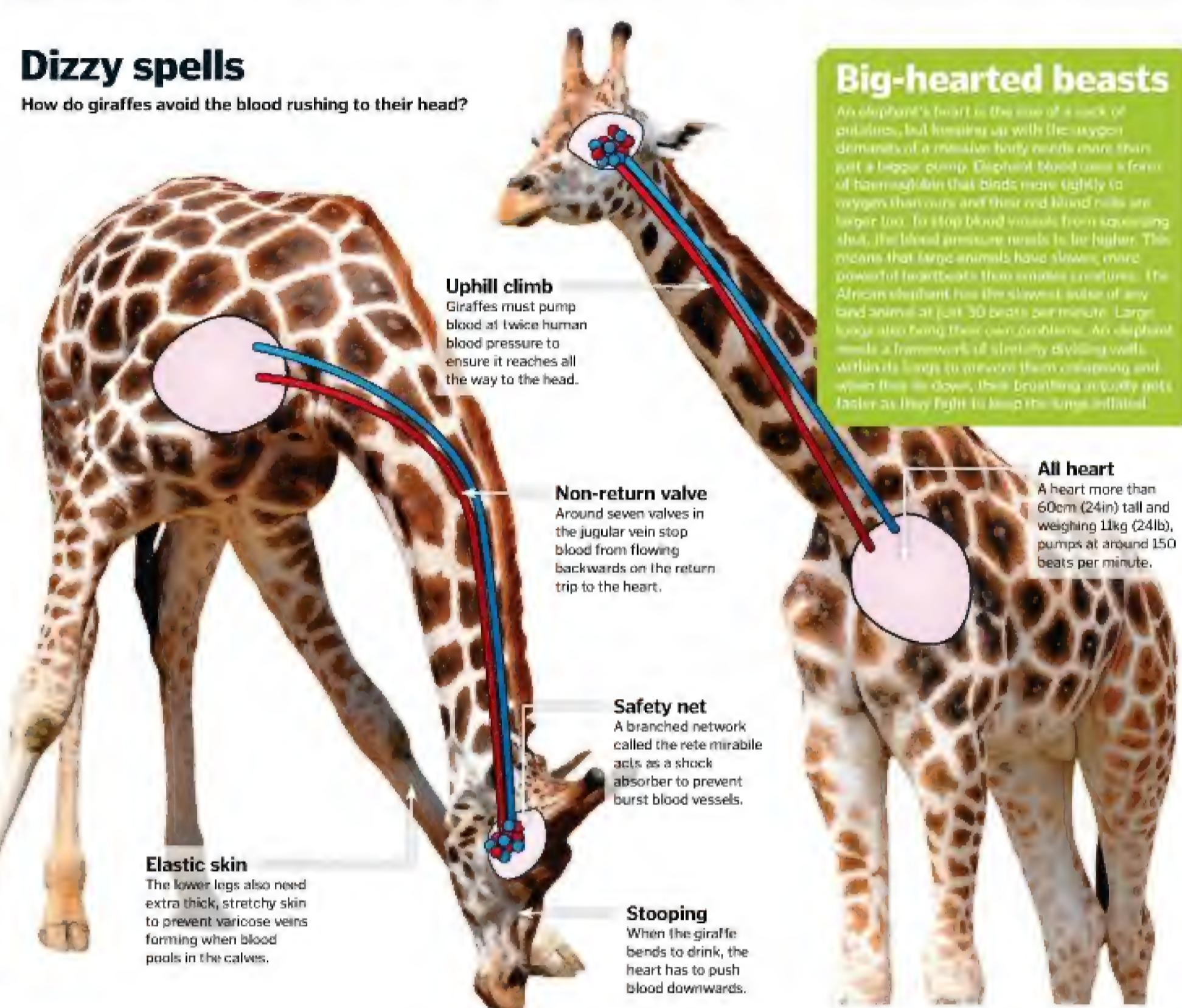
How do giraffes avoid the blood rushing to their head?



Uphill climb
Giraffes must pump blood at twice human blood pressure to ensure it reaches all the way to the head.

Non-return valve
Around seven valves in the jugular vein stop blood from flowing backwards on the return trip to the heart.

Elastic skin
The lower legs also need extra thick, stretchy skin to prevent varicose veins forming when blood pools in the calves.



Big-hearted beasts

An elephant's heart is the size of a sack of potatoes, but keeping up with the oxygen demands of a massive body needs more than just a bigger pump. Elephant blood uses a form of haemoglobin that binds more tightly to oxygen than ours and their red blood cells are larger too. To stop blood vessels from bursting due to the blood pressure needs to be higher. This means that large animals have slower, more powerful heartbeats than smaller creatures. The African elephant has the slowest pulse of any land animal at just 30 beats per minute. Large frogs also have their own problems. An elephant needs a framework of strong, dividing walls within its lungs to prevent them collapsing and when they lie down, their breathing actually gets faster as they fight to keep the lungs inflated.

All heart

A heart more than 60cm (24in) tall and weighing 11kg (24lb), pumps at around 150 beats per minute.

systems, these arthropod monsters simply couldn't get enough oxygen to sustain their massive bodies so they died out.

Even without such drastic environmental shifts, there are very real challenges for giant animals. Most predators generally eat animals smaller than themselves. This allows them to hunt abundant prey and achieve an easy kill with minimum risk to themselves. But carnivores heavier than about 21 kilograms (46 pounds) can't catch small animals fast enough to meet their food requirements. Instead they have to hunt quarry much larger than themselves. This is more dangerous and requires a radical shift in tactics. A large

carnivore also has to cope with irregular mealtimes, with long periods of starvation followed by a stomach-stretching blowout.

Herbivores, meanwhile, face challenges of their own. Plants are relatively poor in nutrients, so they need to eat a lot of them. Giant herbivores like elephants and rhinos can quickly overgraze an area if they don't constantly move on, and their large weight can compact the ground to the point where rainwater doesn't soak in properly and seeds find it difficult to become established. Elephants will uproot trees to get at the topmost leaves, turning savanna into grassland. Elephants can't survive on just grass though, so

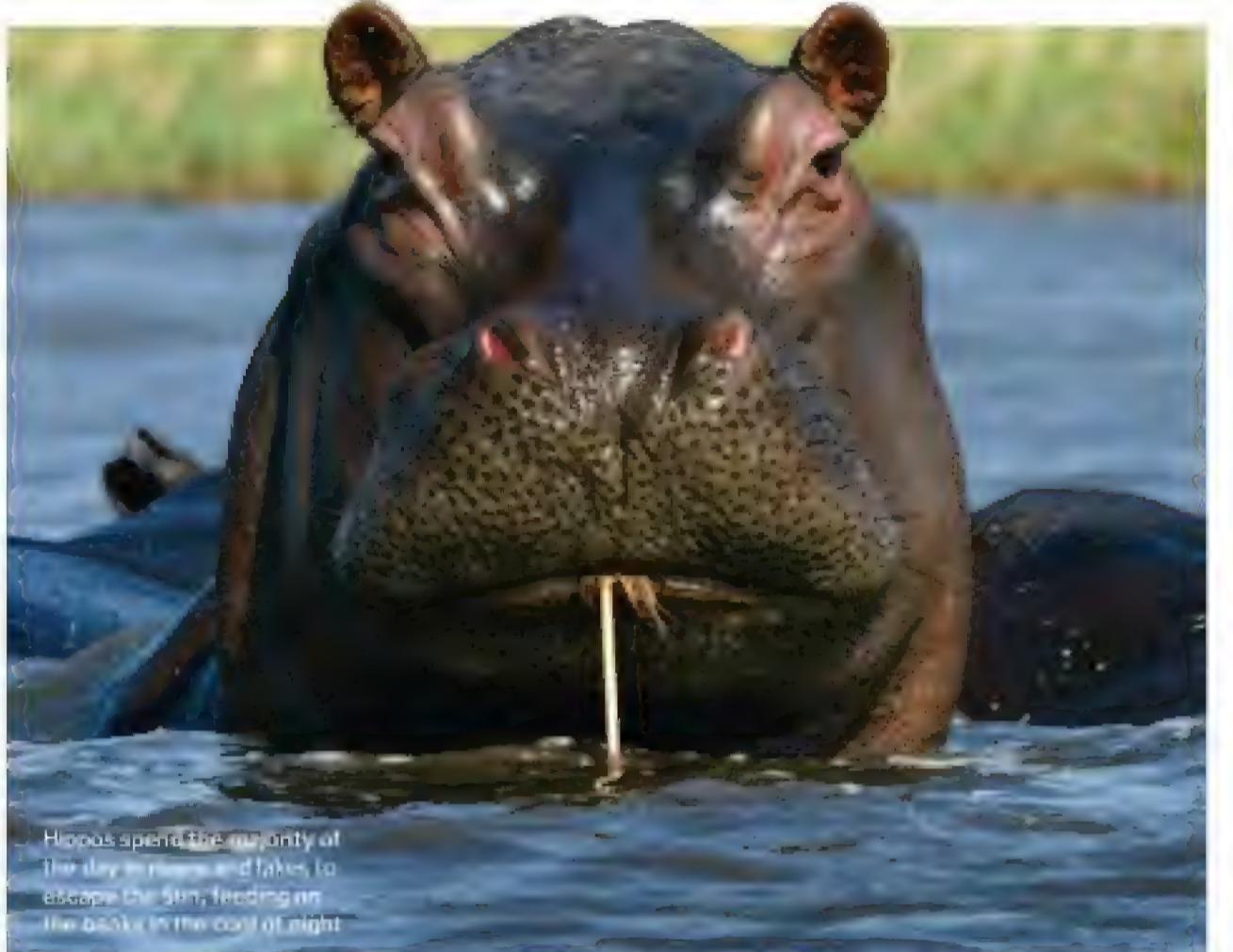
large populations of elephants can become the agents of their own destruction.

A massive body also creates problems for reproduction. If the young are born too small, they are vulnerable to predators; born too large and the extended gestation period places too much strain on the mother. Elephants spend almost two years pregnant and giraffes must be born with much shorter necks in order to prevent complications during birth.

But if nature has shown us one thing, it's that obstacles are there to be overcome. Around the world in virtually every animal group, colossal creatures have risen to the challenge and stomped on it. Let's meet nature's giants... ☺



"Within a given species or genus, the larger variants are normally found in the coldest climates"



Hippos spend the majority of the day in rivers and lakes to escape the sun, feeding on the banks in the cool of night.

The perfect temperature

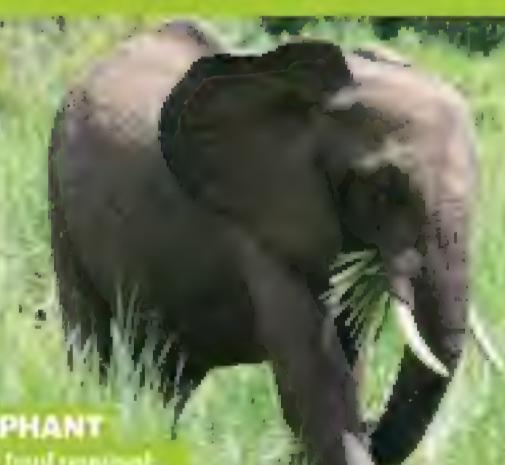
Large animals have intrinsic protection against the cold. The bigger you are, the more heat is generated by your metabolism. Kodiak brown bears don't hibernate in the winter to avoid the freezing temperatures – they do it because there isn't enough food to support their voracious appetite. Within a given species or genus, the larger variants are normally found in the coldest climates – the Siberian tiger is the largest tiger subspecies, for example.

But in hot climates, being large presents the opposite problem: how to get rid of that excess heat? Hippos spend the day in rivers or lakes and only venture out at night to graze. The southern white rhino spends the hottest part of the day wallowing in a mudhole and even tigers will take a dip in the river to cool off – one of the only large cats that does this. Elephants swim too, but when they are on the open savanna their ears act as natural radiators, pumping hot blood through thin skin to shed heat.

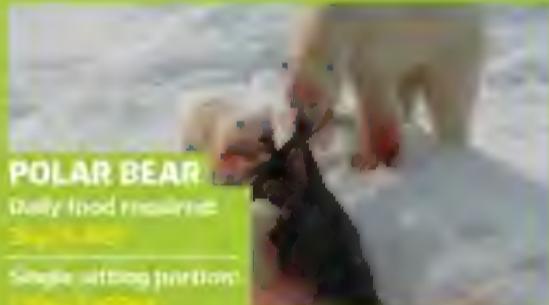
Mighty appetites

An elephant already has to spend between 16 and 30 hours of every day just eating – that's more than 80 per cent of its waking hours! There simply isn't time to eat any more food than that. A big part of the problem is that an elephant's digestion is quite inefficient. In fact, elephant dung still has 50 per cent of the nutrients left in it and is still a viable food source for hyenas, baboons and dung beetles. Gorillas can't digest plant cell walls either, but they don't have the stomach capacity to just munch indiscriminately. Instead they use their prehensile fingers and teeth to strip the edible parts off a plant, like fruit, bark and roots.

In large carnivores, the problem is catching enough food. Tigers are only successful once out of every 10-20 hunting trips. On average they catch just a single deer a week, so they need to be able to eat huge amounts at a single sitting.



ELEPHANT
Daily food required:
1000 kg (2,200 lbs)
Single sitting portion:
200 kg (440 lbs)



POLAR BEAR
Daily food required:
300 kg (660 lbs)
Single sitting portion:
100 kg (220 lbs)



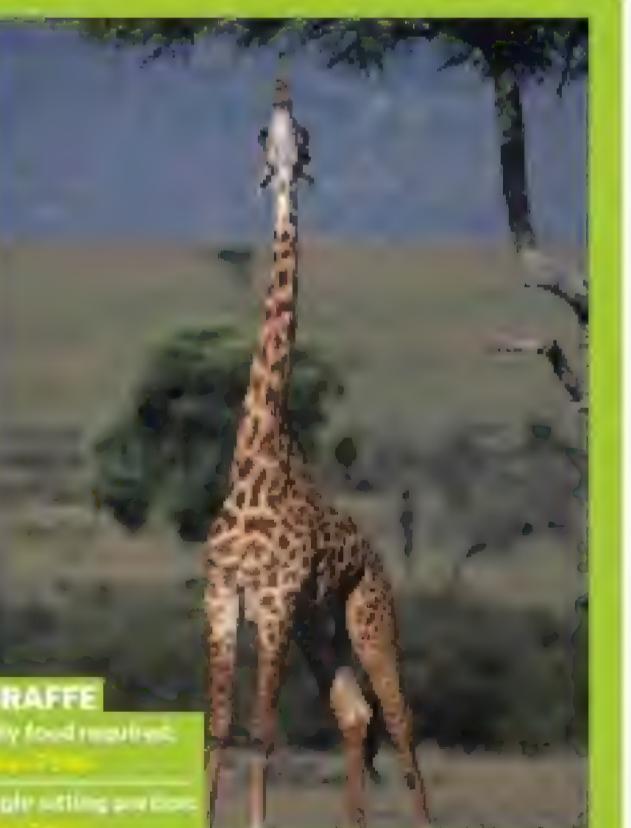
GREEN ANACONDA
Daily food required:
100 kg (220 lbs)
Single sitting portion:
20 kg (44 lbs)



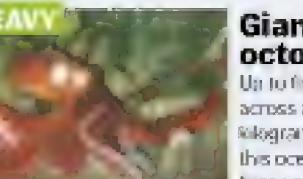
TIGER
Daily food required:
300 kg (660 lbs)
Single sitting portion:
100 kg (220 lbs)



GORILLA
Daily food required:
100 kg (220 lbs)
Single sitting portion:
20 kg (44 lbs)



GIRAFFE
Daily food required:
100 kg (220 lbs)
Single sitting portion:
20 kg (44 lbs)



1. HEAVY
Giant Pacific octopus
Up to five metres (16 feet) across and weighing 50 kilograms (110 pounds), this ocean monster only lives up to five years.



2. HEAVIER
Ocean sunfish
Averaging a ton, this is the largest bony fish on the planet. Females lay 300 million eggs at a time – which is more than any other vertebrate.



3. HEAVIEST
Blue whale
Not just the largest animal alive today, but the largest animal to have ever lived, a blue whale is equivalent to the weight of about 30 elephants, i.e. 200 tons.

Did you know? The giraffe has a prehensile tongue that is 0.5m (1.6ft) long! It's black to protect it from sunburn.

Big game hunting

One of the biggest advantages of being large is that it protects you from predators. But if you are a predator yourself, extreme size can often be a disadvantage. The larger you are, the harder it is to sneak up on prey and the less manoeuvrable you are in comparison. Apex predators normally need huge hunting ranges to find enough food; golden eagles, for instance, patrol over 200 square kilometres (77 square miles) of moorland looking for carrion, fish and rodents, etc.

To overcome this, large predators need to be stealthy. Often they prefer to ambush their victims, rather than run them down. Anacondas lie in wait at watering holes, while brown bears will sit patiently in the river at the top of a salmon leap. Others rely on team tactics. Lions are famous for their group hunting techniques, but Philippine eagles also hunt in pairs, with one bird perching to distract a troop of monkeys, while the other swoops in from behind.



AFRICAN LION
Trophic level: 4
Success rate: 50%



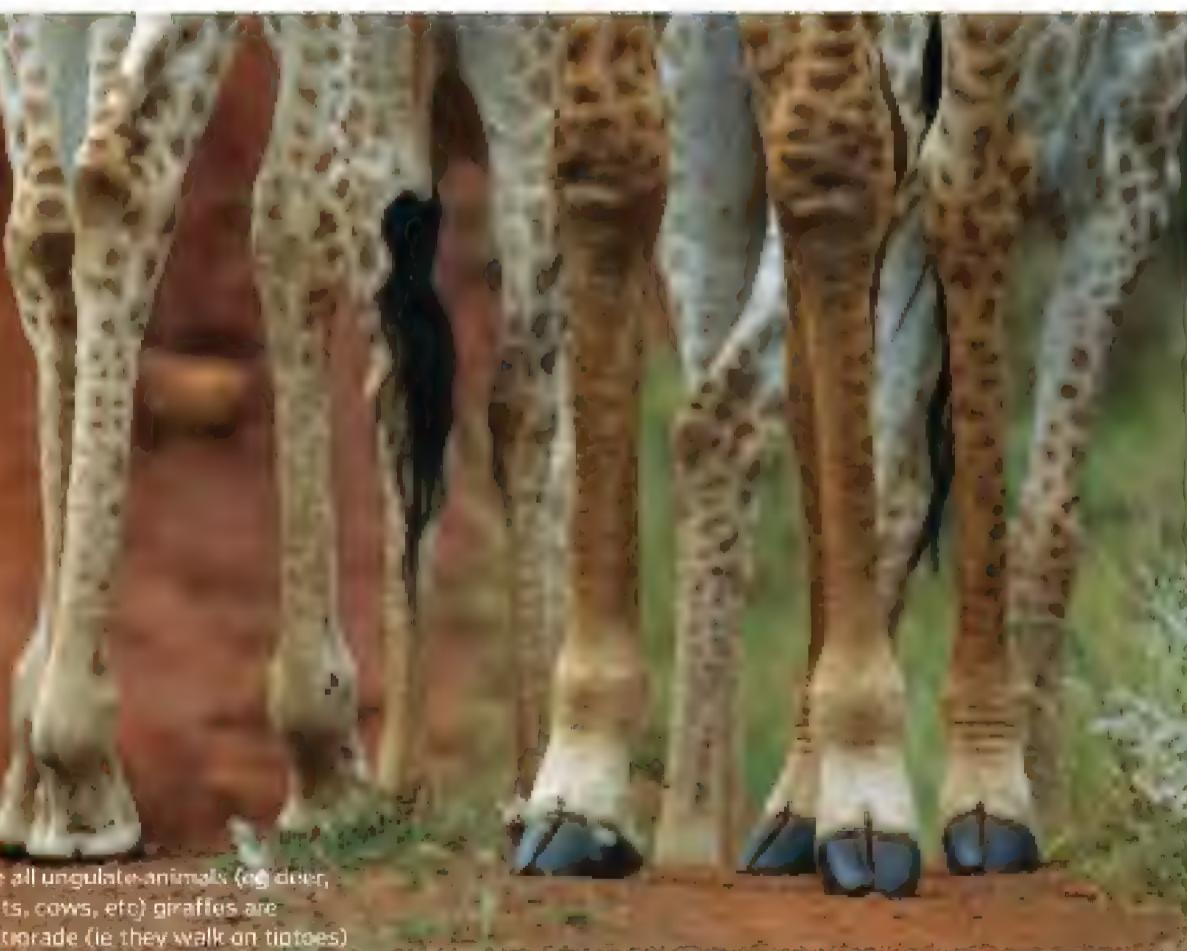
TIGER
Trophic level: 4
Success rate: 10%



GREEN ANACONDA
Trophic level: 3
Success rate: 10%



PHILIPPINE EAGLE
Trophic level: 4
Success rate: 10%



Like all ungulate animals (e.g. deer, goats, cows, etc) giraffes are digitigrade (i.e. they walk on tiptoes)

Don't ever race a giraffe!

The legs of a giraffe are two metres (6.6 feet) long but almost half of this is actually the foot. The joint that functions as a knee is anatomically equivalent to a wrist or ankle. The giraffe balances on the tips of its toenails, but to support its weight these toenail hoofs are 30 centimetres (12 inches) across. Giraffes can gallop at 60 kilometres (37 miles) per hour for short periods, while elephants hit the red line at just 25 kilometres (16 miles) per hour.

Because of the way that their legs must be positioned to support the body weight, elephants have very poor leverage and use a single running gait. Long-distance running is a problem for many very large animals. Tigers, for example, can cover as much as 32 kilometres (20 miles) in a single night's hunting, but they do it at an easy walk. To catch prey they must sneak to within 10-20 metres (33-66 feet) of the victim before they are in pouncing range.

"Giant salamanders can live for over 30 years and keep growing throughout their lifetime"

THE
STATS
ELEPHANTS

HEIGHT 3.5m
WATER DRUNK
PER DAY (LITRES) 85
MAX SKIN
THICKNESS 3.8cm
AVERAGE
TOTAL WEIGHT 6 tons
TUSK WEIGHT 65kg
BRAIN WEIGHT 5kg

DID YOU KNOW? The white rhino has the widest nostrils of any land animal, with nasal passages larger than its brain!

Anatomy of a giant

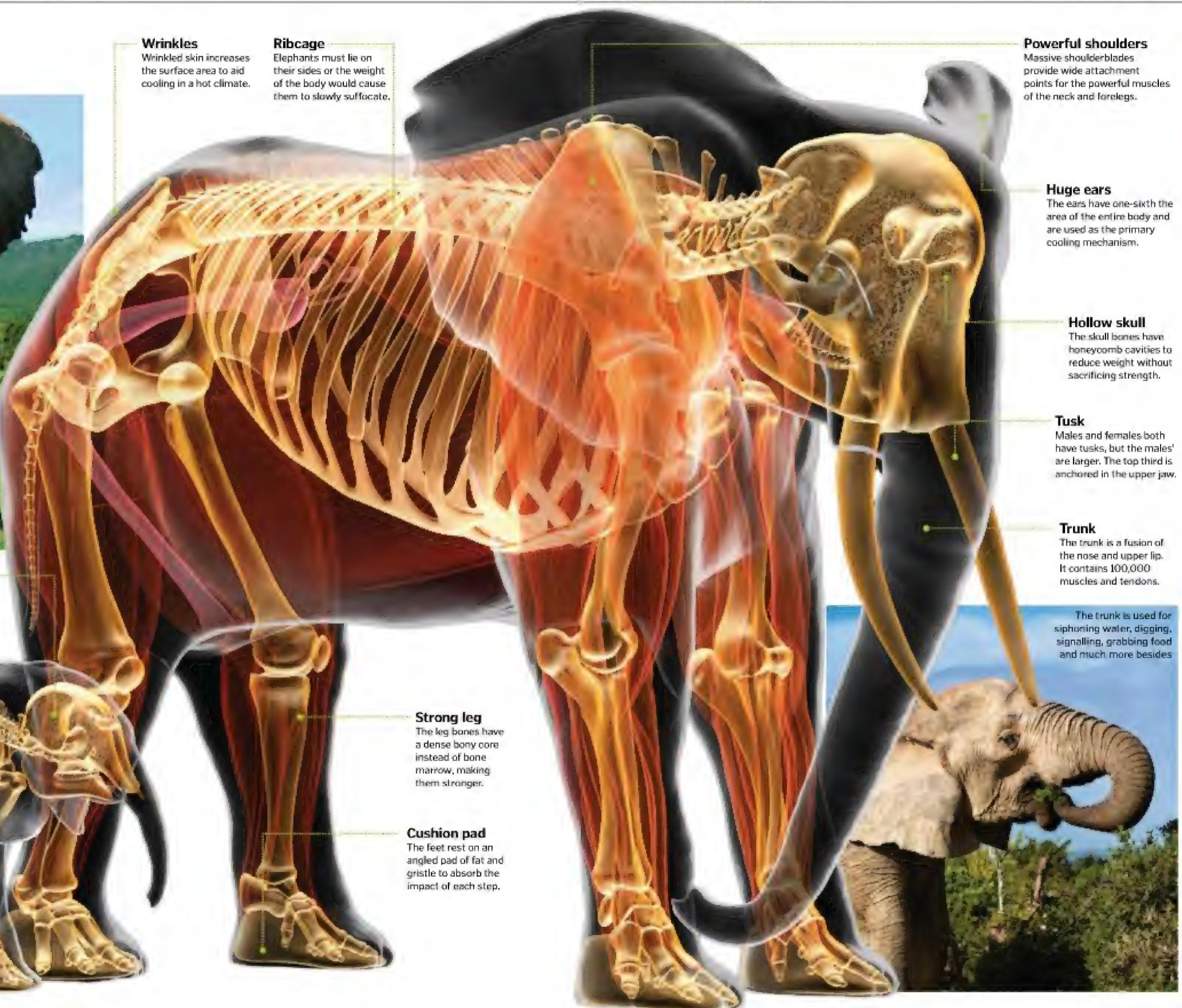
When you weigh between six and seven tons, just standing up is an incredible feat of engineering...



It's hard to believe, but the elephant's closest living relative is a rodent called the hyrax (inset)

Big brain

Elephant brains are three times the size of ours. A newborn elephant's brain is already 30-40 per cent of its adult size.



More big beasts!

Hippopotamus

Hippos are more closely related to whales than they are to rhinos or elephants. They can weigh up to three tons and prefer to spend the day in the river, but on land they can easily outrun a human – so be wary!



Mandrill

The largest monkey, adult male mandrills can weigh over 90 kilograms (77 pounds). They eat mainly fruit, but also sometimes catch small animals and even deer, which they kill with a bite from their long canines.



Red kangaroo

The largest marsupial, red kangaroos can be taller than a man and weigh up to 90 kilograms (99 pounds). They are the only large animal that gets around by hopping. At full pelt, they can move at up to 56 kilometres (44 miles) per hour!

Southern elephant seal

They have the largest size difference between males and females of any land-breeding mammal: male elephant seals are six times heavier than females. A large adult male can weigh up to four tons. Their size has evolved because of brutal territorial contests with other males.



Saltwater crocodile

The largest reptile and also the most widely distributed crocodile species around the world. Males can reach over six metres (20 feet) long and weigh over a ton. They have the strongest bite of any animal alive – it's three and a half times stronger than a tiger's.



Chinese giant salamander

Giant salamanders can live for over 30 years and keep growing throughout their lifetime. Large specimens can be 1.5 metres (4.9 feet) long and weigh 50 kilograms (110 pounds). They have tiny eyes, but are very sensitive to vibration, which enables them to catch quick-moving fish and frogs.



Giant golden-crowned flying fox

Although tiny compared to the other animals here, this is the largest bat on Earth. It's under 1.3 kilograms (3 pounds), but can have a wingspan of 1.5 metres (4.9 feet). They mainly eat figs.



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5 TOP FACTS

VIEW FROM SPACE

DO YOU KNOW?

1 Sierra Madre Oriental This mountain range marks the border between the Coahuila and Nuevo León regions in Mexico. Satellite imagery reveals them to look like the spines of fossilised dinosaurs.

2 Baffin Island sea ice From space these chunks of sea ice floating among tiny ice crystals, known as grease ice, look like swirling wispy white clouds when captured using satellite imagery.

3 Spider Crater This impact crater in north Western Australia has leg-like ridges of tough sandstone which have stood the test of time better than the surrounding crater.

4 Polar auroras When the aurora borealis/australis geomagnetic storms are viewed from space they somehow manage to look even more alien than they do when viewed from below.

5 Great Barrier Reef The magnificent blue-green glow of corals in the Great Barrier Reef off the coast of Queensland are particularly impressive when viewed using satellite imagery.

DID YOU KNOW? Richat's outer rings are the youngest while those at the core indicate significantly older rock.

The Eye of the Sahara

What is the Richat Structure and how did it form?

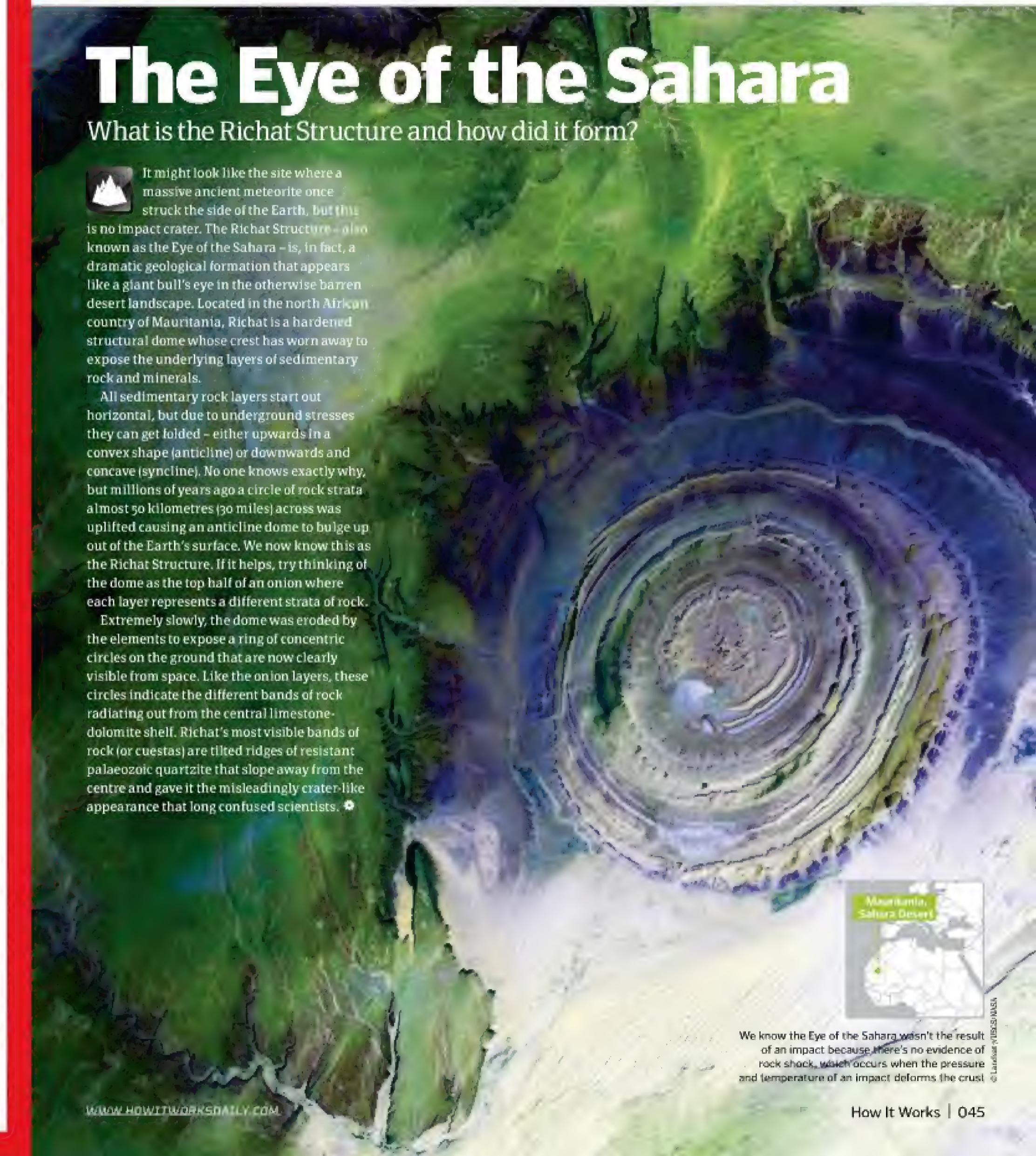




It might look like the site where a massive ancient meteorite once struck the side of the Earth, but this is no impact crater. The Richat Structure – also known as the Eye of the Sahara – is, in fact, a dramatic geological formation that appears like a giant bull's eye in the otherwise barren desert landscape. Located in the north African country of Mauritania, Richat is a hardened structural dome whose crest has worn away to expose the underlying layers of sedimentary rock and minerals.

All sedimentary rock layers start out horizontal, but due to underground stresses they can get folded – either upwards in a convex shape (anticline) or downwards and concave (syncline). No one knows exactly why, but millions of years ago a circle of rock strata almost 50 kilometres (30 miles) across was uplifted causing an anticline dome to bulge up out of the Earth's surface. We now know this as the Richat Structure. If it helps, try thinking of the dome as the top half of an onion where each layer represents a different strata of rock.

Extremely slowly, the dome was eroded by the elements to expose a ring of concentric circles on the ground that are now clearly visible from space. Like the onion layers, these circles indicate the different bands of rock radiating out from the central limestone-dolomite shelf. Richat's most visible bands of rock (or cuestas) are tilted ridges of resistant palaeozoic quartzite that slope away from the centre and gave it the misleadingly crater-like appearance that long confused scientists. *



We know the Eye of the Sahara wasn't the result of an impact because there's no evidence of rock shock, which occurs when the pressure and temperature of an impact deforms the crust.

“Such is the power of glaciers that the bottoms of fjords are often deeper than the ocean they open into”

HEAD2
HEAD2
RECORD FIJORDS



1. LONGEST
Scoresby Sund
 Located on the east coast of Greenland, the huge Scoresby Sund inlet is believed to be the longest fjord system found anywhere in the world.



2. NARROWEST
Nærøyfjord
 Branching off Norway's larger and more famous Sognefjord near Bergen, the Nærøyfjord is just 250 metres (820 feet) wide at its narrowest point.



3. DEEPEST
Fiordo Baker
 This fjord in Chile boasts the largest known river-deepening of 1,344 metres (4,409 feet) – that equates to about three Empire State Buildings!

DID YOU KNOW? The milky-turquoise colour of the glacier meltwater in a fjord is caused by super-fine debris called 'rock flour'.



How fjords form

As a product of the epic clash between ice and rock, find out how these amazing valleys are created

 Fjords are long, steep-sided coastal valleys that are flooded by the sea. The majority of fjords developed during the last ice age, peaking approximately 20,000 years ago. Glaciers dominated the landscape, snaking their way to the ocean and tearing through anything that stood in their path. These massive valleys are typically found in mountainous, coastal areas of the Atlantic and Pacific oceans, and are common in Norway, Sweden, Greenland, Canada, Chile, New Zealand and the US state of Alaska.

As a glacier carved its way through the rock, it cut a distinctive U-shaped valley. The floor was flat and the sides were steep and high. As the massive river of ice – which could reach up to three kilometres (1.9 miles) thick – bore through the valley floor, it picked up rocky debris and carried it along for the ride, adding to the glacier's rock-shattering abrasive power. This rubble eventually made its way to the head of

the glacier and was pushed in front of it as the glacier travelled – known as a terminal moraine. Such is the sheer power of the glacier to gouge out rock that the bottoms of fjords are often deeper than the ocean that they open into. For example, the deepest point of the Sognefjord in Norway is approximately 1,300 metres (4,265 feet) below sea level whereas the sill is just 100 metres (328 feet) below sea level. As the ice age came to a close, the oceans flooded into these extra-deep glaciated valleys, forming what we now know as fjords.

It's the rock formations of a glaciated landscape that are left for us to see today. The glacial moraine will still be present at the entrance of a fjord – a large sill acting as a barrier between fjord and open ocean. There are also other features such as skerries, which are rocky islands within a fjord that can be both large and mountainous or small and treacherous to navigate in a boat.

Life in a fjord

The water in a fjord is distinctly stratified, which affects the animals and plants that call it home. Dense seawater flows over the sill at the fjord's entrance and sinks to the bottom. Hardy deep-water animals such as sea cucumbers live down here in the thick mud, deposited over thousands of years. Deep-water coral reefs can also be found, providing valuable habitats for other species of algae, deep-water fish, crustaceans and molluscs.

Higher up in the water column, algae can thrive on the steep rocky sides of the fjords, providing food for hundreds of fish species. Oxygen-rich fresh water from rivers and meltwater streams runs into the fjord too, which combined with sunlit conditions can serve as the perfect environment for phytoplankton blooms.

The sheltered nature of a fjord can also offer a safe haven for larger marine-mammal visitors such as seals and whales, which often go there to mate.



DISCOVER THE PAST!

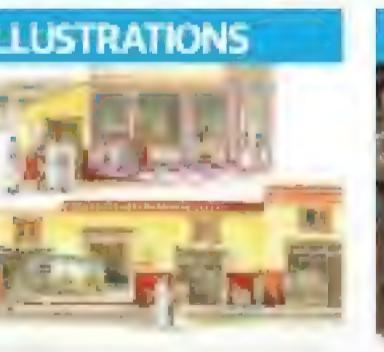
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STRANGE BUT TRUE HORNETS BEE-WARE

How can bees get their own back on hornets?

- A Cook them
- B Drown them
- C Make fun of them



Answer:
Bees do have one secret weapon. They can swarm around the scout and vibrate to turn up the heat. Bees can withstand 48 degrees Celsius (118 degrees Fahrenheit), but hornets can only stand 46 degrees Celsius (115 degrees Fahrenheit) and so roast.

DID YOU KNOW? Petrichor is taken from the Greek for stone (petroj) and the fluid found in the veins of Greek gods (ichor).

Hornets vs honeybees

How 30 giant hornets can exterminate a colony of 30,000 honeybees in mere hours



Giant hornets have a taste for honeybee larvae and pupae, which they feed to their own young. Once a hornet scout locates a honeybee nest it releases a potent pheromone to signal the location to other hornets. Upon their arrival, as few as 30 giant hornets can wipe out an entire bee colony a thousand times larger. The hornets are four to five times the size of the honeybees and, with every minute that passes, one hornet will massacre at least five bees. Strong tarsal claws and powerful mandibles mean the invaders are capable of ripping bee heads from bodies and simply casting them aside. The bees do everything they can to protect their hive – attempting to sting through the hornets' impenetrable armour – but within three hours the colony is wiped out. The hornets now have access to enough honey to gorge themselves, and all the bee larvae and pupae to take back to their offspring.

Japanese giant hornet biology

A consummate killer, the hornet is built for mass murder

Wings

A 7cm (2.8in) wingspan enables the hornet to fly 96km (60mi) per day at up to 40km/h (25mph).



Armour plating

Multiple layers of chitin form an impenetrable armoured casing that can defend against most stingers.

Compound eyes

Hornets have extremely good eyesight enabling them to spot potential victims from afar.

Stinger

This pumps out a large dose of excruciating venom that contains an enzyme potent enough to dissolve human skin. Japanese giant hornets kill 40 Japanese people every year.

Mandibles

Powerful jaws are capable of beheading bees with a single slice.

Tarsal claws

These vice-like claws grip the prey while the hornet makes short work of rending multiple victims in seconds.

The smell of rain

Find out why precipitation creates a distinctive aroma that's the same all over the world



It's possible to smell rain before it has even fallen. Lightning has the power to split atmospheric nitrogen and oxygen molecules into individual atoms. These atoms then react to form nitric oxide, which in turn can interact with other chemicals to form ozone – the aroma of which is a bit like chlorine and a specific smell we've grown to associate with rain. When the scent carries on the wind, we can predict the rain before it falls.

Another smell associated with rain is petrichor – a term coined by a couple of Australian scientists in the mid-Sixties. After a dry spell of weather, the first rain that falls brings with it a very particular aroma that is the same no matter where you are. Two chemicals are responsible for the production of this indescribable odour called petrichor. One of the two chemicals is released by a specific bacteria found in the earth; the other is an oil secreted by thirsty plants. These compounds combine on the ground and, when it rains, the smell of petrichor will fill your nostrils. •



"For some varieties of salmon runs can cover staggering distances of up to 3,200 kilometres (2,000 miles)"

STOP
FACTS
GREAT MIGRATIONS

Arctic terns

1 The Arctic tern's annual round trip from the Arctic Circle down to the Antarctic Circle in the south sees this little seabird travel at least 32,000 kilometres (20,000 miles).

Monarch butterflies

2 Like the sockeye salmon, the monarch butterfly also embarks on a one-off migration travelling vast distances of up to 4,800 kilometres (3,000 miles).

Wildebeest

3 Fuelled by hunger, 1.5 million wildebeest migrate in a giant 2,900-kilometre (1,800-mile) loop in eastern Africa every year. They are following the rains that replenish the grass.

Red land crabs

4 Millions of the red land crabs native to Christmas Island crawl out of the forests before the monsoon season and march sideways for up to a week towards the shore.

Sperm whales

5 Groups of 50-ton adult sperm whales bachelors embark upon epic journeys that can see them clocking up thousands of miles before being reunited with the female whales.

DID YOU KNOW? A fish has the same number of scales all its life, as the fish grows so too does each scale

The life cycle of a sockeye salmon

Discover the epic journey a salmon undertakes from birth to death

 The life aquatic is something of an adventurous existence if you're a migratory Pacific salmon such as the sockeye. While most of its life is spent out in the ocean, such seasonal changes as the shortening of the length of a day trigger the once-in-its-lifetime migration back to the freshwater rivers of its youth.

The annual salmon run performed by the adult fish takes place usually in late-spring to summer. This instinctive behaviour, written in the genes, sees the salmon battle its way from the ocean back along estuaries, past

fishermen's hooks, up treacherous bear-lined rapids and on to the gravel beds of the stream where it was born. For some varieties of salmon runs can cover staggering distances of up to 3,200 kilometres (2,000 miles) up the Yukon River. It's unknown quite how the salmon knows where it's heading, but it's thought it could be following its nose and tracking a certain familiar scent.

The death-defying voyage is exhausting for the adult salmon and, once it arrives at the spawning ground and lays/fertilises its eggs, it will die. The new eggs develop into the next

generation of salmon that will embark on precisely the same cycle of life.

Around six to nine weeks after the eggs have been laid and fertilised in the gravel, the young will begin to hatch in the freshwater where they will remain developing for up to three years. First hatching as alevins they develop from defenceless small fry through to well-camouflaged parrs, then smolts and eventually to adults. After that they will migrate to the ocean for their first taste of saltwater where they will continue their growth into maturity.

Ladders for fish

When salmon make their way back upstream to spawn, they can encounter a number of manmade barriers, such as dams and locks. To ensure the fish can progress, humans have built stepped channels that go over or around the obstructions. Known as fish ladders these help the salmon overcome otherwise impassable obstacles and carry on the rest of their perilous journey. The most common type of fish ladder looks like a long staircase of mini waterfalls up which the fish can leap, but other varieties include elevators, pools-and-weirs and baffles.

The Bonneville Dam on the Columbia River is a major salmon thoroughfare from the Pacific to freshwater spawning areas between Oregon and Washington. Hundreds of thousands of salmon take this route every year so the addition of the Bonneville fish ladder means these aquatic commuters can get where they need to go.

Where do sockeye salmon live?



Life stages of a salmon

A sockeye goes through a number of dramatic physical – not to mention geographical – changes in its lifetime...



Eggs
The tiny translucent eggs spawned in the gravel beds of freshwater rivers and streams are a pinkish-orange colour. Each male salmon fertilises over 2,000 eggs, which hatch after a few weeks.



Alevin
An alevin hatches out of the soft eggshell but remains hidden in the gravel for another month. It will feed on a nutrient-rich yolk sac that remains attached to the small alevin's body, until it is absorbed.



Fry
The salmon is now starting to look like a fish. At five to ten weeks old, it leaves the gravel nest and learns to swim and feed on minute aquatic insects. At this point the salmon are very vulnerable.

Gill cover

Also called the operculum, this hard but flexible outer lining shields the gills. When the fish gulps in water, it seals off its mouth and throat to allow the water to pass over its gills, which absorb oxygen.

Lateral line

This is a series of fluid-filled canals (similar to what we have in our ears), which sense vibrations through the water and help the fish hear, or distinguish movements in the water and the direction in which it is flowing.

Scales

These overlapping plates provide flexible protective body armour against predators. Scales grow in at the fry stage of life. As they develop, they form rings like you see in tree trunks. If a scale falls out a new one grows but without the inner growth rings.

Dorsal fin

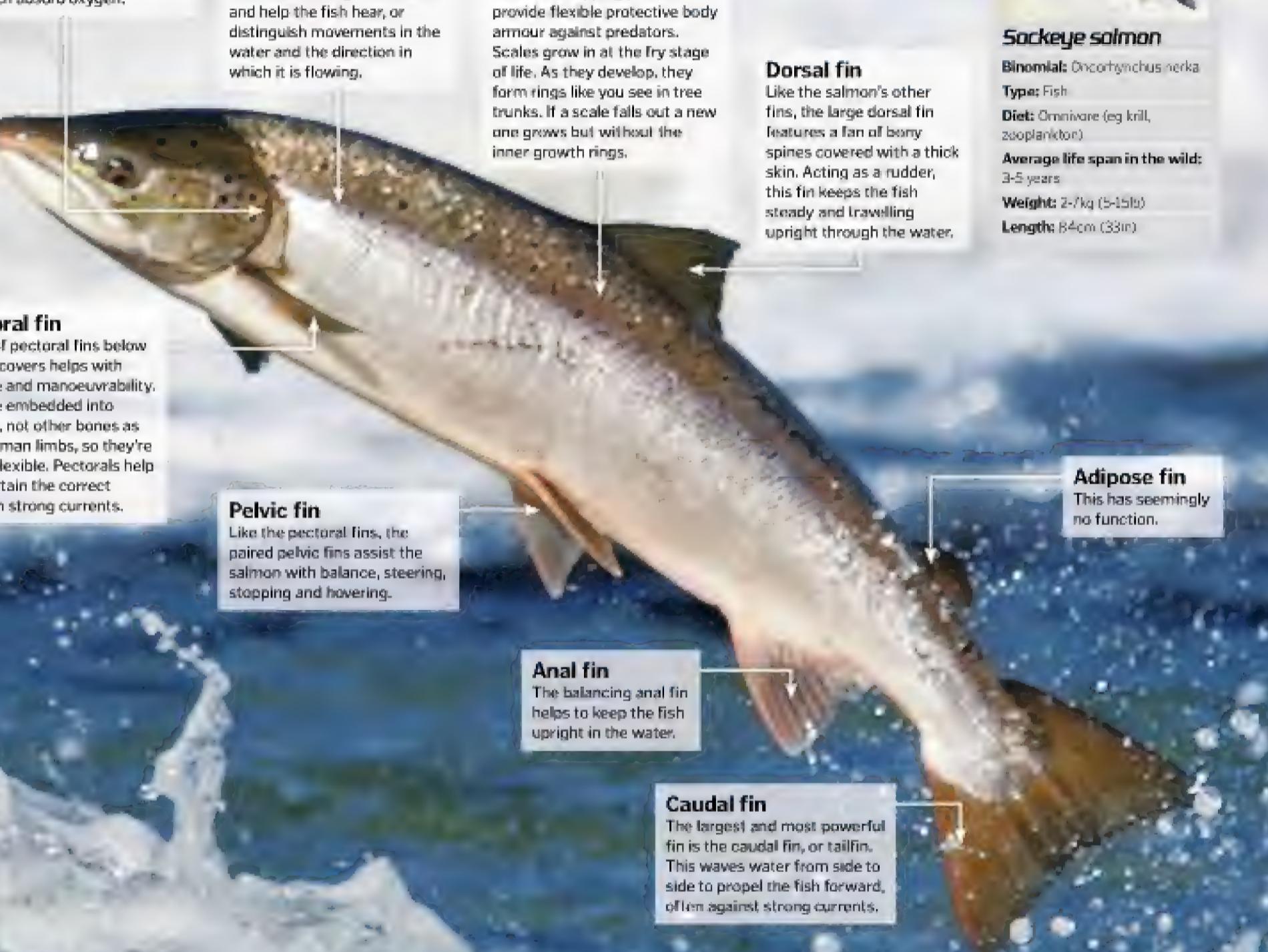
Like the salmon's other fins, the large dorsal fin features a fan of bony spines covered with a thick skin. Acting as a rudder, this fin keeps the fish steady and travelling upright through the water.

The statistics...



Sockeye salmon

Binomial: *Oncorhynchus nerka*
Type: Fish
Diet: Omnivore (eg krill, zooplankton)
Average life span in the wild: 3-5 years
Weight: 2-7kg (5-15lb)
Length: 84cm (33in)



Adipose fin

This has seemingly no function.



Parr
After a few months, when the fish is about 15cm (6in), the fry becomes a parr. It's still vulnerable and so develops dark vertical stripes on its sides for camouflage. It will remain at this stage for up to three years.



Smolt
By the time the salmon is one to three years old, it no longer bears any stripes but appears silver. Smolts head for the sea, and in the estuary undergo smoltification as they adjust to the saltwater.



Adult
Once it gets to the ocean, the adult quickly reaches maturity. The skin is silvery blue with black speckles while it lives at sea, but when it returns to freshwater to spawn it turns red with a greenish head.



Spawning adult
The adults then make the perilous trek from ocean to stream. The spawning female digs a nest called a redd into which she lays her eggs for a male to fertilise. Within about two weeks the fish will have died.



BIONIC HUMANS

Discover the medical technology that really could make us better, faster, stronger...



Bionics experts attempt to build mechanical and electronic devices to mimic biological functions. With the exception of the brain, the human body can essentially be broken down and rebuilt using a combination of mechanical, electronic and biological technologies.

A bionic limb strips human biology back to its constituent parts. Tough materials like aluminium and carbon fibre replace the skeleton, motors and hydraulics move the limb, while springs replace the tendons that store and release elastic energy. A computer controls motion and wires relay electrical signals, as nerves would have done in a real limb. Users are now even able to control these limbs with their minds (see 'The power of thought').

Technology is also in development to replace individual muscles and tendons following

injury. The synthetic muscles are made from a polymer gel, which expands and contracts in response to electrical currents, much like human muscle. The tendons are made from fine synthetic fibres designed to imitate the behaviour of connective tissue.

The mechanical nature of limbs makes them excellent candidates for building robotic counterparts, and the same applies to the human heart. The two ventricles, which supply blood to the body and lungs, are replaced with hydraulically powered chambers. However, it's not just the mechanical components of the human body that can be replaced; as time goes on, even parts of the complex sensory system can be re-created with technology.

Cochlear implants, for example, use a microphone to replace the ear, while retinal implants use a video camera to stand in for the

human eye. The data that they capture is then processed and transformed into electrical impulses, which are delivered to the auditory or optic nerve, respectively, and then on to the brain. Bionic touch sensors are also in development. For example, the University of California, Berkeley, is developing 'eSkin' – a network of pressure sensors in a plastic web.

This could even allow people to sense touch through their bionic limbs. Replacing entire organs is one of the ongoing goals of bionic research. However, breaking each organ down and re-creating all of its specialised biological functions is challenging.

If only part of an organ is damaged, it's simpler to replace the loss of function using bionics. In type 1 diabetes, the insulin-producing beta cells of the pancreas are destroyed by the immune system. Some

STRANGE BUT TRUE LIMB LOSS CULPRIT

What is the number one cause of limb amputation?
A Car accident B Diabetes C Lightning



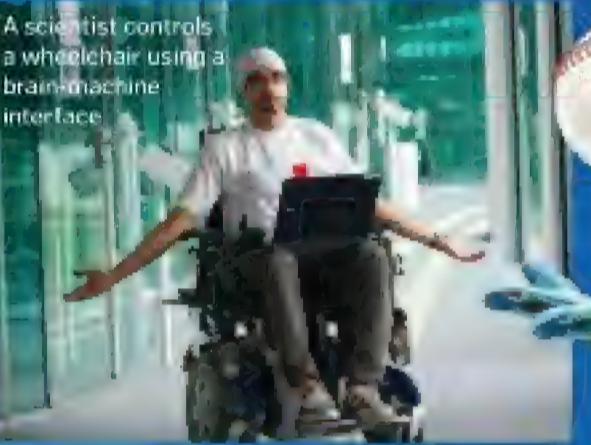
Answer:
Diabetes is the leading cause of lower limb amputation. High blood sugar damages the nerves and blood vessels in the feet, which can lead to ulcers and eventually gangrene.

DID YOU KNOW? An artificial heart implant operation costs about £80,000 (\$125,000) and £1,500 (\$18,000) a year to maintain

The power of thought explained

Cutting-edge bionic limbs currently in development allow the user to control movements with their own thoughts. Technically called 'targeted muscle reinnervation' it's a groundbreaking surgical technique that rewires the nerves in an amputated limb. The remaining nerves that would have fed the missing arm and hand are rerouted into existing muscles. When the user thinks about moving their fingers, the muscles contract, and these contractions generate tiny electrical signals that can be picked up by the prosthetic.

The prosthetic is then programmed to respond to these muscle movements, taking each combination of signals and translating it into mechanical movement of the arm. Some of the most sophisticated have 100 sensors, 26 movable joints and 17 motors, all co-ordinated by a computer built into the prosthetic hand.

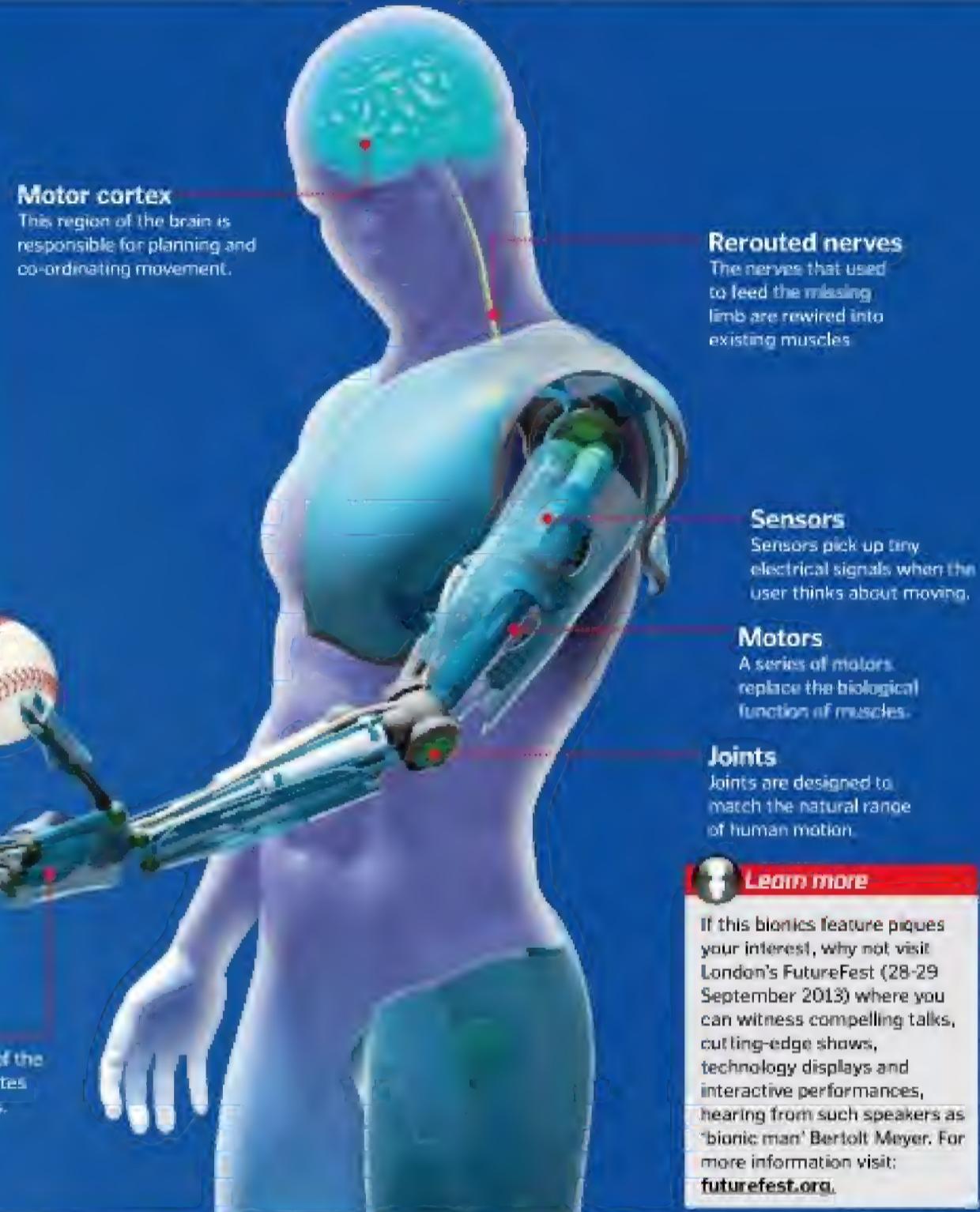


Computer
A computer in the hand of the prosthetic arm co-ordinates all the other components.

patients are now fitted with an artificial pancreas; a computer worn externally, which monitors blood sugar and administers the correct dose of insulin as required.

Entire organ replacements are much more complicated, and scientists are turning back to biology to manufacture artificial organs. By combining 3D printing with stem cell research, we are now able to print cells layer by layer and build up tissues. In the future, this could lead to customised organ transplants made from the recipient's very own cells.

Advances in bionics mean that already limbs are emerging that exceed human capabilities for weight bearing and speed. That said, the sheer complexity of our internal organs and how they interact means that it is not yet possible to fully replace man with machine. But maybe it's just a matter of time...



Learn more

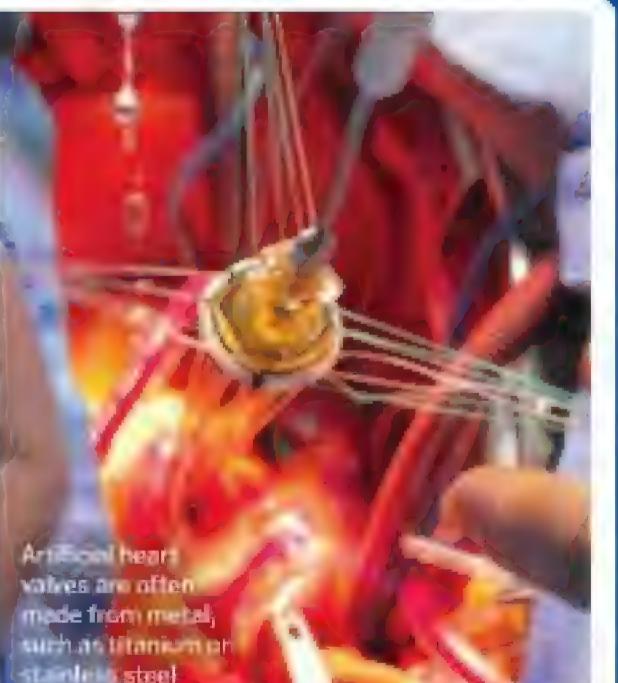
If this bionics feature piques your interest, why not visit London's FutureFest (28-29 September 2013) where you can witness compelling talks, cutting-edge shows, technology displays and interactive performances, hearing from such speakers as 'bionic man' Bertolt Meyer. For more information visit: futurefest.org.

The right materials

One of the most important factors in biomedical engineering is biocompatibility – the interaction of different materials with biological tissues.

Implanted materials are often chosen because they are 'biologically inert' and as a result they don't provoke an immune response. These can include titanium, silicone and plastics like PTFE. Artificial heart valves are often coated in a layer of mesh-like fabric made from the same plastic used for soft drink bottles – Dacron. In a biological context, the plastic mesh serves as an inert scaffold, allowing the tissue to grow over the valve, securing it in place. Some scaffolds used in implants are even biodegradable, providing temporary support to the growing tissue, before harmlessly dissolving into the body.

Bionic limbs are worn externally, so their materials are chosen for strength and flexibility as opposed to biocompatibility. Aluminium, carbon fibre and titanium are all used as structural components, providing huge mechanical strength.



Artificial heart valves are often made from metal, such as titanium or stainless steel



"Some of the newest technologies are so advanced they outperform their biological counterparts"

KEY DATES
BIONICS FIRSTS

500 BCE

The first known mention of a wooden prosthetic limb, worn by a prisoner after his foot was amputated.

1957

The first cochlear implant is created. Sounds are unprocessed, but it does help with lip reading.

1982

The first successful artificial heart implant operation is performed at the University of Utah.

2011

The first artificial trachea transplant takes place in Sweden, using a synthetic scaffold coated in stem cells.

2013

The Argus II retinal implant is licensed, enabling patients with retinitis pigmentosa to see again.

DID YOU KNOW? In 1812 a prosthetic arm was invented that could be moved using cables attached to the opposite shoulder.

Building a bionic human

Advances in technology make it possible to build limbs with components that mimic the function of the skeleton, musculature, tendons and nerves of the human body. Meanwhile, the sensory system can be replicated with microphones, cameras, pressure sensors and electrodes. Even that most vital organ, the heart, can be replaced with a hydraulic pump. Some of the newest technologies are so advanced that the components actually outperform their biological counterparts.

Retinal implant

Argus II, Second Sight

A camera mounted on a pair of glasses captures real-time images and transmits them wirelessly to an implant on the retina. The implant contains 60 electrodes and, depending on the image, will generate different patterns of electrical signals, which are then sent to the remaining healthy retinal cells. These cells are activated by the signals, and carry the visual information to the brain for processing.

Interface: Nerve cells respond to electrical signals made by the implant.

Rods and cones: Light detection by the eye's own cells is not necessary.

Wireless technology: Video signals are sent wirelessly to the implant.

Implant: The implant transmits signals via 60 electrodes.

Ganglion cells: The long axons of these cells make up the optic nerve.

Cochlear implant

Nucleus 6, Cochlear

A cochlear implant has four main components. A microphone, worn near the ear, detects audio and transmits a signal to a sound processor. The processor then arranges the signal and sends it to a built-in transmitter. The transmitter passes the signal to an implanted receiver/stimulator, which transforms it into electrical stimuli for the electrodes. Finally these signals are relayed to the auditory nerve.

Cochlea: Many thousands of nerve cells project from the cochlea to the auditory nerve.

Receiver/stimulator: Signals from the external transmitter are received through the skin by this device.

Microphone and processor: The equipment for detecting and processing the sound is worn over the ear.

Electrical wires: The signals are turned into a series of electrical impulses sent via wires.

Electrodes: Between 4 and 22 electrodes interact with the nerves of the cochlea.

Aorta: The right-hand artificial ventricle sends oxygenated blood to the body.

Pulmonary artery: The left-hand artificial ventricle sends blood to the lungs to pick up more oxygen.

Pneumatic tubing: Pulses of air from an external pump push blood out of the heart.

Synthetic ventricles: Plastic ventricles replace both of the lower chambers.

Artificial heart

Total Artificial Heart, SynCardia Systems

Plastic hearts can be implanted to replace the two ventricles of the heart. Plastic tubing is inserted to replace the valves, and two artificial chambers are also attached. The heart is then connected to a pneumatic pump, worn in a backpack, which sends bursts of air to the chambers, generating the pressure that's required to pump blood around the body.

Bionic arm

Joints: Joints replicate the range of motion in a human arm and hand.

Computer: A computer processes information coming in from the electrodes.

Electrodes: Electrodes pick up signals from nerves rerouted into nearby muscles.

Motors: Beneath the casings are motors to provide movement in the arm.

Touch-sensitive prosthetics

Touch sensor: Sensors on the prosthetic detect touch and send a signal to the electrodes.

Electrodes: A panel of electrodes sits across the flattened nerve.

Signalling: The electrodes send a small electrical signal to the nerve, causing it to fire.

Sheath: The nerve is encased and flattened to maximise contact area with the electrodes.

Nerve: Sensory nerves transmit incoming signals to the brain.

Bionic leg

Spring: A spring replaces the Achilles' tendon, providing elastic energy storage.

Powered ankle: A motorised ankle works in place of the calf muscle.

Computer: Microprocessors analyse the user's movement and adjust the leg accordingly.

Joint: The joints are all programmed to move in co-ordination with one another.

Bionic limbs

3D-printed organs

3D printing is the future of manufacturing and biologists are adapting the technology in order to print using living human cells. The cells are laid down in alternating layers alongside a transparent gel-like scaffold material. As the cells fuse, the scaffold disappears. The movement of many prosthetics is controlled externally, using cables attached to other parts of the body, or using a series of buttons and switches. New technology is emerging to allow the user to move the limb using their mind (see 'The power of thought'). The next logical step in this process is developing technology that enables the prosthetic limb to sense touch, and relay the information back to the user. DARPA-funded researchers have developed FINE, a flat interface nerve electrode (see below left) which brings nerves into close contact with electrodes, allowing sensory data to pass to the brain.

Ekso skeleton

Ekso Bionics has made bionic exoskeletons to allow people with lower limb paralysis to walk. Ekso supports their body and uses motion sensors to monitor gestures and then translate them into movement.

Artificial kidney

The University of California, San Francisco, is developing a bionic kidney. At about the size of a baseball, it contains silicone screens with nano-drilled holes to filter blood as it passes. It will also contain a population of engineered kidney cells.

Man-made immunity

Leuko-polymerosomes are plastic 'smart particles' that mimic cells of the immune system. They are being designed to stick to inflammatory markers in the body and could be used to target drug delivery to infections and cancer.

Robotic blood cells

The Institute for Molecular Manufacturing is developing nanotechnology that could increase the oxygen-carrying capacity of blood. Known as respirocytes, the cells are made atom by atom – mostly from carbon.

054 | How It Works

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HEAD
HEAD
TAKING DRUGS



1. GOOD
Dry powder inhaler
This inhaler delivers medicine in a powdered form but the patient must do all the work to get the powder into their lungs



2. BETTER
Nebuliser
Straightforward to use but can be noisy during operation. Some medicine inevitably gets lost to the surroundings (toxic雾) making dosing unpredictable.



3. BEST
Metered dose inhaler
Giving an accurately measured dose and very portable these can be inhaled at any pace, so are suitable for all age groups.

DID YOU KNOW? In most nebulisers, 80 per cent of the medication atomises within the first five minutes



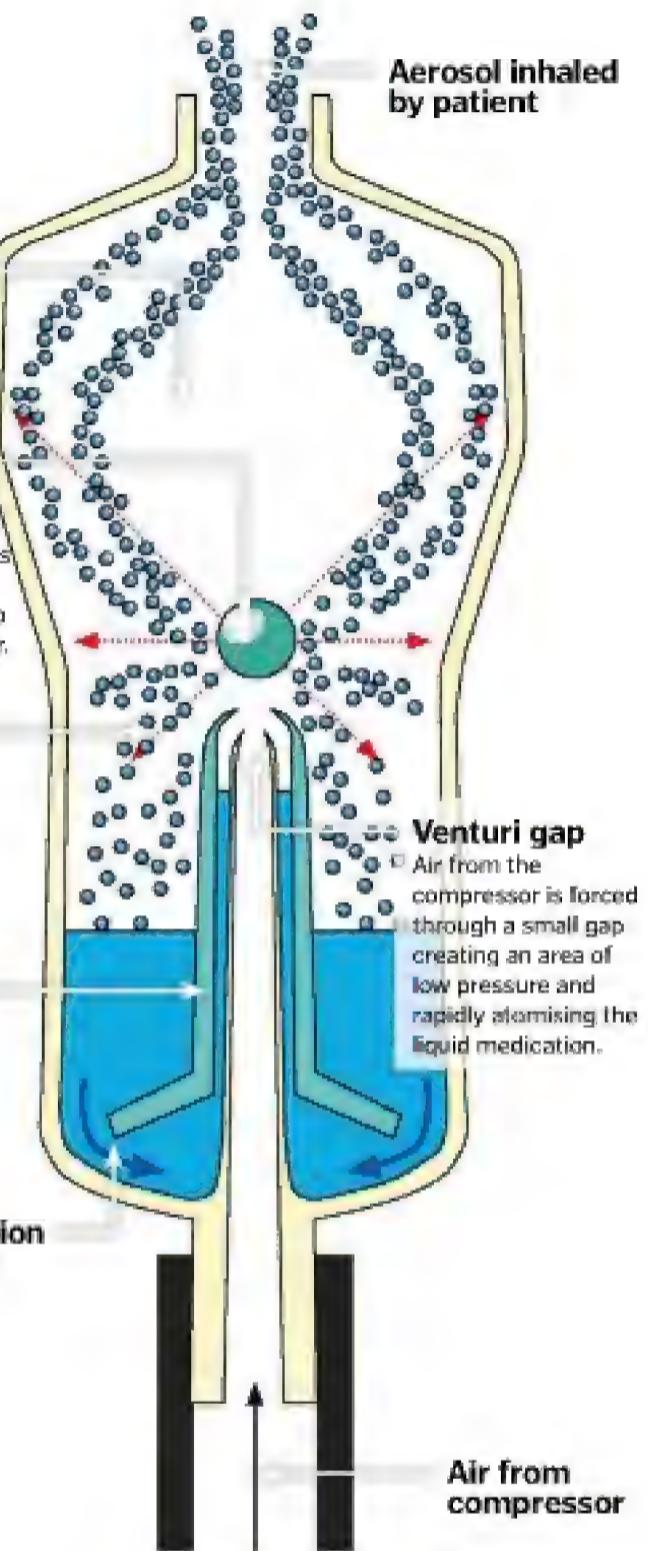
Inhalation chamber
A fine mist accumulates in this section ready for the patient to breathe in.

Baffle
Particles of different sizes are sorted by the baffle allowing droplets between one and five micrometres to pass to the inhalation chamber.

Larger drops
Droplets larger than five micrometres are deflected to the reservoir below for renebulisation.

Feeder tubes
Liquid medication is sucked up these tubes towards the area of low pressure.

Medication solution



Nebulisers demystified

How do these devices vaporise medication to treat respiratory problems?



For some treatments swallowing a pill or having an injection won't get to the root of the problem. Nebulisers offer an effective way to administer drugs directly to the lungs by vaporising a liquid solution of the drug into a fine mist of airborne liquid particles one to five micrometres in diameter. Primarily used to treat lung conditions such as chronic obstructive pulmonary disease, asthma and cystic fibrosis, the mist is inhaled allowing the drugs easier targeting of problem areas.

Jet nebulisers use an electric pump to force compressed air through a tiny gap – the Venturi. Here an area of low pressure forms due to the Bernoulli principle, which states that a stream of faster moving air will always have a lower pressure. A liquid solution of medicine is sucked up into small feeding tubes by this pressure difference where it meets the fast stream of air and atomises into an aerosol mixture of tiny liquid drops and air. The patient inhales this mixture through a mouthpiece or

mask, holding their breath for a few seconds, which deposits the fine particles in the lungs instead of them being immediately exhaled.

Baffles inside the medicine container control particle size, trapping any droplets that are too big and directing them back towards the reservoir for renebulisation. Particles larger than five micrometres are unlikely to get as far as the lungs before depositing, while those finer than one micrometre tend not to deposit at all, as they're so light, and are exhaled.



"Along with the Snapdragon S4 Pro system-on-a-chip, [it] is also fitted with an inductive charging coil"



DID YOU KNOW? The new Nexus 7 is said to offer up to nine hours of video playback or ten hours of web browsing

Inside the new Nexus 7

Google's latest Nexus 7 has the most detailed screen ever created for a tablet – and it comes with a bevy of other advanced technology too

INFO The new Nexus 7, the second generation of the Google-made tablet, is a 17.8-centimetre (seven-inch) device which currently can boast the highest-resolution tablet screen of its size in the world.

This record comes courtesy of the 323-pixel-per-inch (ppi) panel display, which is unsurpassed in any other tablet on the market – and that includes Google's own larger Nexus 10, which clocks in at only 300 ppi.

It's not just a one-trick pony though. In addition to the Nexus 7's record-breaking screen is a host of other cutting-edge hardware. Along with the impressive specifications delivered by the tablet's Snapdragon S4 Pro system-on-a-chip, the new Nexus 7 is also fitted with an inductive charging coil. This coil is designed to work with the Qi wireless interface

standard and, partnered with a compatible charging device, allows the tablet to be topped up wirelessly by electromagnetic induction, bolstering a growing range of products doing away with traditional wired chargers.

In terms of software, the new Nexus 7 comes pre-installed with the latest Android operating system: 4.3 Jelly Bean. In terms of connectivity Wi-Fi, Bluetooth, NFC and LTE are all supported – the latter broadly so with seven LTE data frequencies enabled in both North America and Europe; a feat that no other tablet can lay claim to. A broad range of frequencies means that the one device can be used in conjunction with a variety of network suppliers, such as AT&T and Verizon in the US and Vodafone and Orange in the UK, rather than requiring individual network-specific models. ■

Why does ppi matter?

Arguably the most advanced piece of technology on the new Nexus 7 is the 323 ppi screen. This is a vast improvement on the original, which featured only 216 ppi. It's also a world record for a 17.8-centimetre (seven-inch) tablet.

The greater number of pixels you can squeeze into an inch of a device's panel, the higher the panel's overall resolution will be. As such, screens with high ppi counts are capable of displaying media with superior fidelity (ie. crispness and detail) than those with lower counts. Typically high ppi screens are therefore associated with expensive, larger panels, such as those used in hi-def computer monitors.

Importantly though, having a physically large screen does not in itself require a high ppi count, with many larger (and cheaper) panels delivering low ppi counts and poor fidelity. To find such a small screen with such a high ppi count in the Nexus 7 is something of a technological leap.

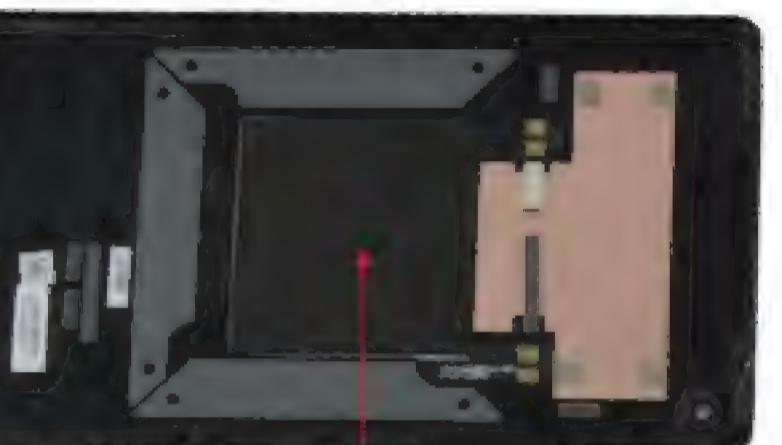


Learn more

In this issue's Group Test, we pit three of the latest tablets head to head, including the second-gen Nexus 7. See which comes out on top on page 88.

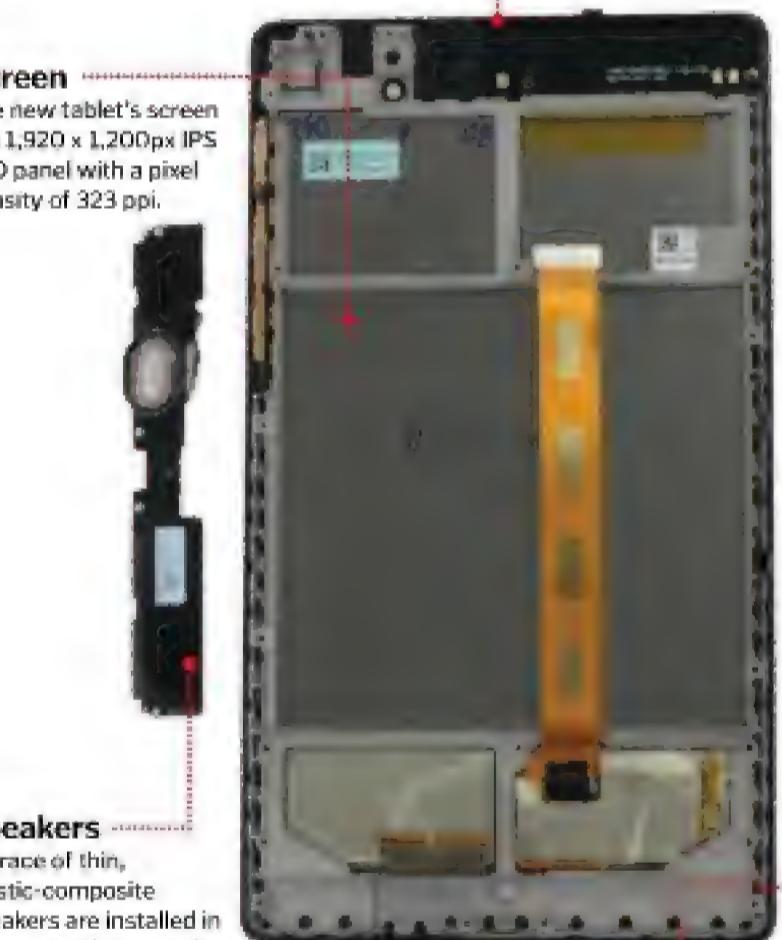
Nexus 7 teardown

We identify the next-gen tech powering this hot new tab



Inductive charging coil

A built-in inductive charging coil means the tablet can now be recharged wirelessly.



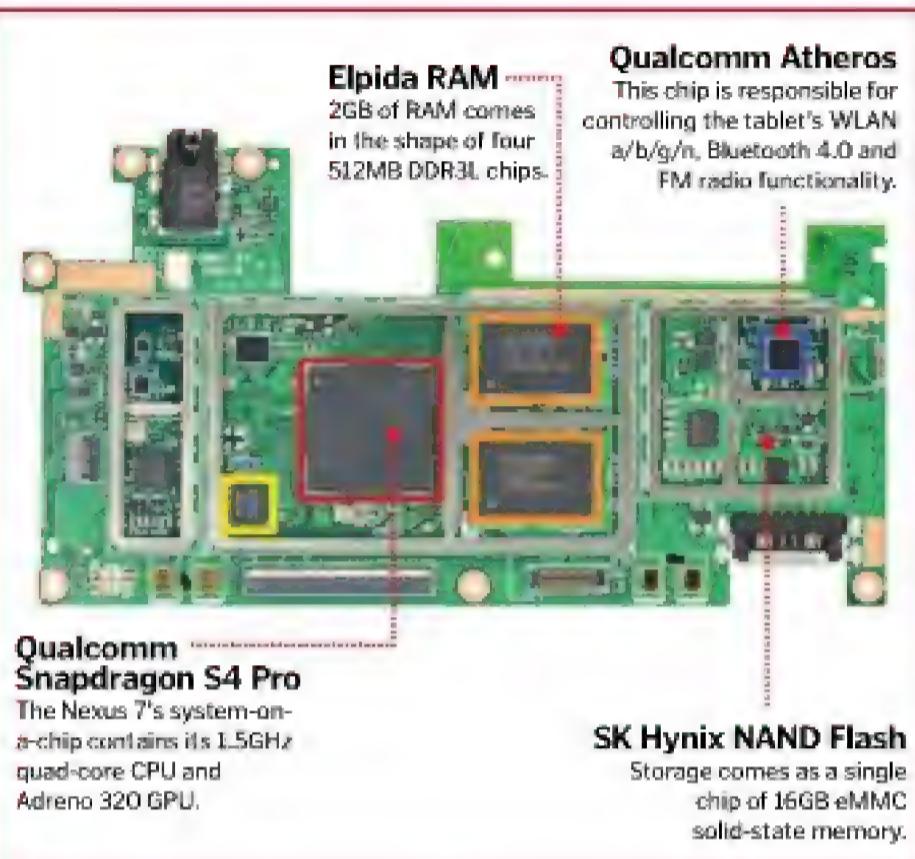
Screen

The new tablet's screen is a 1,920 x 1,200px IPS LCD panel with a pixel density of 323 ppi.



Speakers

A brace of thin, plastic-composite speakers are installed in the top and bottom of the Nexus 7's case.

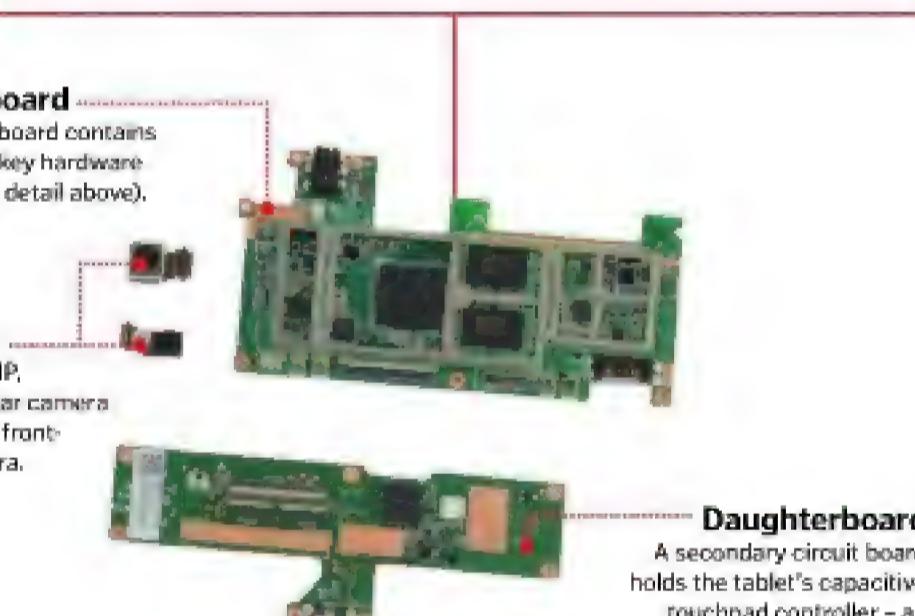


Elpida RAM

2GB of RAM comes in the shape of four 512MB DDR3L chips.

Qualcomm Atheros

This chip is responsible for controlling the tablet's WLAN a/b/g/n, Bluetooth 4.0 and FM radio functionality.



Motherboard

The motherboard contains a variety of key hardware (explored in detail above).



Cameras

There's a 5MP, autofocus rear camera and a 1.2MP front-facing camera.



Battery

The 3,950mAh battery is rated at 3.8V and 15Wh; it offers an extra hour of usage over the original.



Daughterboard

A secondary circuit board holds the tablet's capacitive touchpad controller – an ELAN integrated circuit.

The statistics...

Nexus 7 [second gen]

Height: 200mm (7.9in)

Width: 114mm (4.5in)

Depth: 8.7mm (0.3in)

Weight: 290g (10.2oz)

Screen size: 178.3mm (7in)

Screen resolution: 1,920 x 1,200px (323 ppi)

Battery: 3,950mAh

Storage: 16/32GB

Rear camera: 5MP

Front camera: 1.2MP

CPU: 1.5GHz quad-core Krait

GPU: Adreno 320

RAM: 2GB

OS: Android 4.3 Jelly Bean

New Nexus 7
With a 1,920 x 1,200px IPS screen, a 1.5GHz quad-core CPU and 2GB of RAM, the Galaxy Note 8.0 is the most hi-def seven-inch tablet ever.

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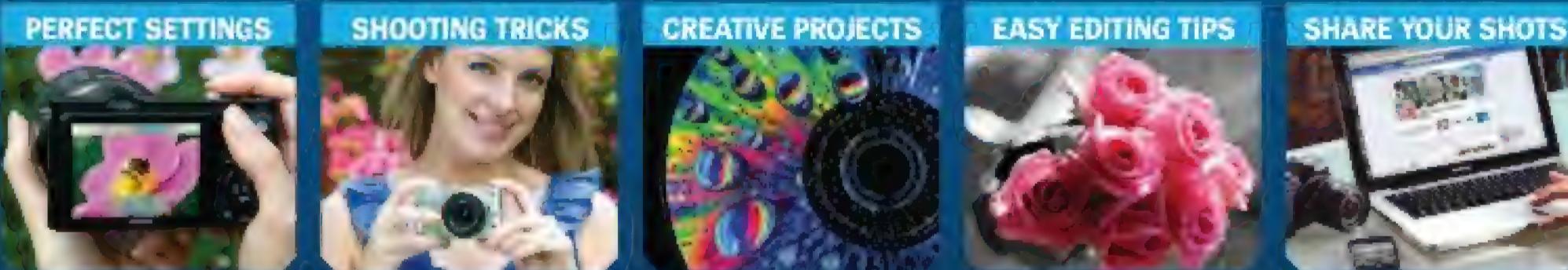
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THE STATS

XPERIA Z ULTRA

DIMENSIONS 179x92x6.5mm CPU 2.2GHz quad-core

WEIGHT 212g DISPLAY 1,920x1,080px BATTERY 3,000mAh

DID YOU KNOW? The first commercial waterproof mobile phone was the LG Conu 502S released in 2005.

Waterproof smartphones

How do these electronic devices carry on working even when underwater?



Today there are two main methods for waterproofing a smartphone: physical barriers such as port covers and sealed seams that prevent liquid entering externally, and nanocoatings that penetrate the device entirely and actively repel water. While both techniques are used, the most effective is the latter, enabling devices to be water resistant without compromising on size and aesthetics.

Once on the phone, the ultra-thin polymer layer then dramatically reduces its surface energy, forcing any water that comes into contact with it to bead up and be repelled.

Simply put, the coating acts in a similar way to the waxy feathers on a duck's back, preventing water from infiltrating the top layer and forcing it to run off the sides. Obviously, in the case of a smartphone, this action would prevent water from penetrating the delicate internal components. However, due to the vapour disposition process, even if water were to penetrate the mobile's casing, each internal component would also be coated with the polymer, protecting them until the water evaporated or was dried off manually. *

A phone worth splashing out on

We pick out the key components that keep the Xperia Z Ultra super-dry

Port covers

Each port on the Z Ultra comes with a protective cover. These prevent water entering while submerged.

Tough materials

Thanks to a hardened glass front and back covers, plus encircling metal frame, the phone can remain underwater for up to 30 minutes.



Depth

As the Z Ultra is IP55/IP58 certified, it can be submerged in up to 1.5m (4.9ft) of freshwater without risk of damage. It is also protected from low-powered jets of water.

Waterproof phone rivals

1 Motorola Defy

With a single-core 800MHz CPU, 512MB of RAM, a 1,540mAh battery and a small 9.4-centimetre (3.7-inch) screen, the Defy is very much an entry-level water-resistant phone.



2 Samsung Galaxy S4 Active

With a quad-core 1.9GHz Snapdragon CPU, 2GB of RAM and Android 4.2.2 installed, the S4 Active is a decent-spec, good all-round smartphone that can take the plunge.



3 Sony Xperia Z Ultra

With a huge 16.3-centimetre (6.4-inch) screen, 2.2GHz quad-core CPU and 8MP camera, the Z Ultra is by far the largest and highest-spec waterproof phone on the market to date.



"Using digital technologies with the internet, school is becoming a multimedia experience"

KEY DATES

PCs IN SCHOOL



DID YOU KNOW? In English primary schools, there are currently around 1.8 students to every computer.

Digital classrooms

From virtual lessons to interactive whiteboards, discover how new technology is revolutionising the way we learn

 Technology is now at the heart of many classrooms, providing students with access to a whole new way of learning. Using digital technologies, combined with the internet, school is becoming a multimedia experience. Indeed, in 2012 there were 1.5 million iPads in use in education, as well as over 20,000 educational apps.

Of course, the internet has brought a huge resource to the digital classroom, granting instant access to a wealth of online information and educational tools. Many universities are uploading free materials to massive open online courses (or MOOCs) like iTunes U and Coursera, providing global access to free world-class education. Classrooms and labs are now also often equipped with microphones, speakers and webcams, opening up opportunities for collaborations across the globe.

Access to these digital educational resources is no longer limited to a single, rarely used computer in

the corner; in fact, interactive whiteboards are now the focal point of many classrooms. A stylus, pen or finger is used to interact with a whiteboard, on which is projected an image of the computer screen. The user's movements are detected by the board and relayed back to the computer, allowing the user to write and draw on the screen (see 'Next-gen whiteboards' boxout for more detail).

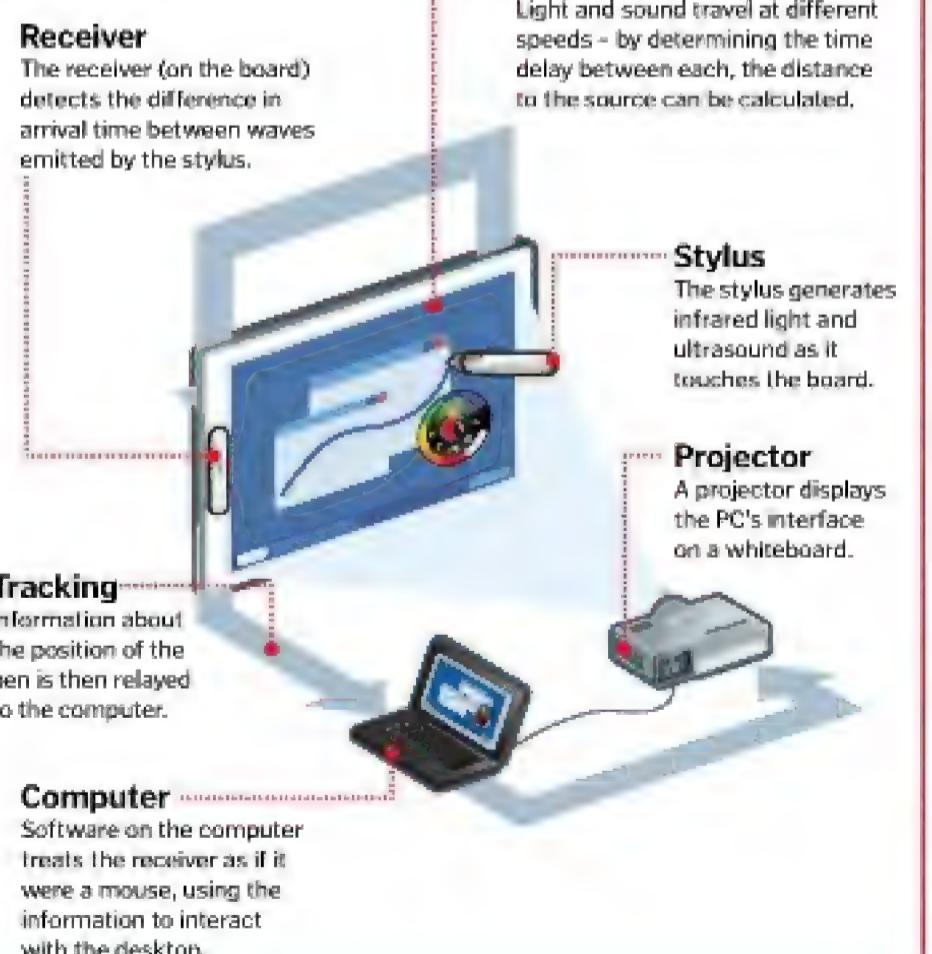
The interactive whiteboard is so much more than a digital chalkboard though. The pen-style interface means that many models come with bespoke software capable of handwriting recognition, converting everything that is written on the board into a digital archive. There are also programs available that allow anything drawn on the screen to be printed, recorded, shared and rewatched later. This has opened up possibilities for remote learning, allowing students unable to attend the physical classroom to still participate virtually. ☀

What technology makes a whiteboard interactive?

Interactive whiteboards use a variety of technologies to provide the interface between user and screen. Infrared whiteboards use infrared wavelengths directed across the surface of the board. When a pen touches the board, it interferes with the light, allowing the point of contact to be calculated. Similarly, ultrasound whiteboards use the deflection of ultrasound waves to detect a stylus's movements.

Some whiteboards, like the eBeam made by Luidia pictured here, do not actually need an electronic board at all, but use a detector which is mounted to the side of a traditional whiteboard.

The eBeam system actually combines both infrared and ultrasound. By using the two together, differences in the time taken for the waves of light and sound to travel across the board enable the location and direction of the pen to be pinpointed. This works in a similar way to predicting the distance of a storm based on the time delay between seeing the lightning strike and then hearing the thunder.



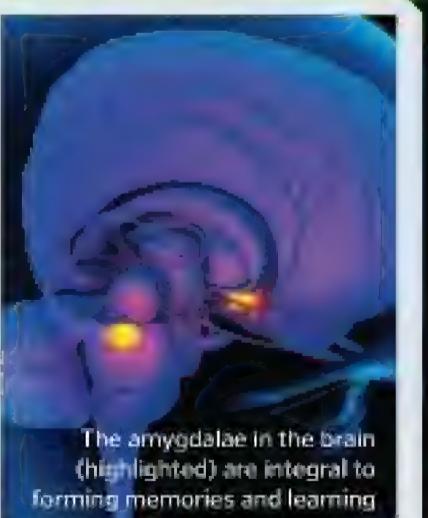
How do we learn digitally?

As we learn, connections between neurons in the brain are reinforced; the more they are used, the stronger they become and the more easily we are able to recall the information.

Digital classrooms provide an engaging environment to reinforce memory. Different people find that they learn more easily in some ways than others - some preferring to watch, others preferring to interact, etc. Digital classrooms are able to offer tailored ways of learning, appealing to a wide range of preferences, and enabling classes to

be adapted to individual students. One of the major advantages is that technology makes learning more fun, keeping pupils engaged for longer and providing memorable experiences to really help the knowledge stick.

One technique being increasingly employed to enhance learning through technology is 'gamification' - essentially turning learning into a game. The best educational games allow the student to learn without even realising it. Many of these games also include virtual rewards and leaderboards for an extra incentive.



DID YOU KNOW? Since 1973 eight separate spacecraft have visited the Jovian system


JUICE: Mission to Jupiter

Meet the ESA's new spacecraft that will explore the Solar System's biggest planet as well as its fascinating icy moons

Jupiter and its moons are part of a sort of 'mini Solar System', called the Jovian system that we still don't fully understand. Jupiter itself holds the record of being the largest planet in the Solar System, with storms the size of Earth and a unique atmosphere making it a world of great interest.

Orbiting Jupiter are dozens of natural satellites that are equally intriguing, with the four largest being the Galilean moons: Io, Europa, Ganymede and Callisto. Each of these is fascinating in its own right: Europa, for instance, is an icy moon with a possible

saltwater ocean lurking beneath its surface, while Ganymede bears tantalising hints of a thin ozone layer not too dissimilar to Earth's.

With all that in mind, Jupiter has been the focus of several exploratory missions over the past few decades, from passers-by like the Voyager spacecraft to the Galileo orbiter that

remained in the system from 1995 to 2003. Now,

however, a new breed of spacecraft is on its way to study the Jovian system like never before. Already en route is NASA's solar-powered Juno probe, which will arrive in July 2016, and by 2030 the European Space Agency (ESA) will hopefully have its own spacecraft in orbit around the gas giant, called the Jupiter Icy Moons Explorer, or JUICE for short.

"Europa is an icy moon with a possible saltwater ocean beneath its surface, while Ganymede bears hints of a thin ozone"

Where it will launch...

ESA, CNES (the French space agency) and the private company Arianespace conduct many of their rocket launches from the Guiana Space Centre, a spaceport located near Kourou in French Guiana that has been operational since 1968. Notable launches from here include the Herschel space telescope and the Galileo satellites used for global positioning.

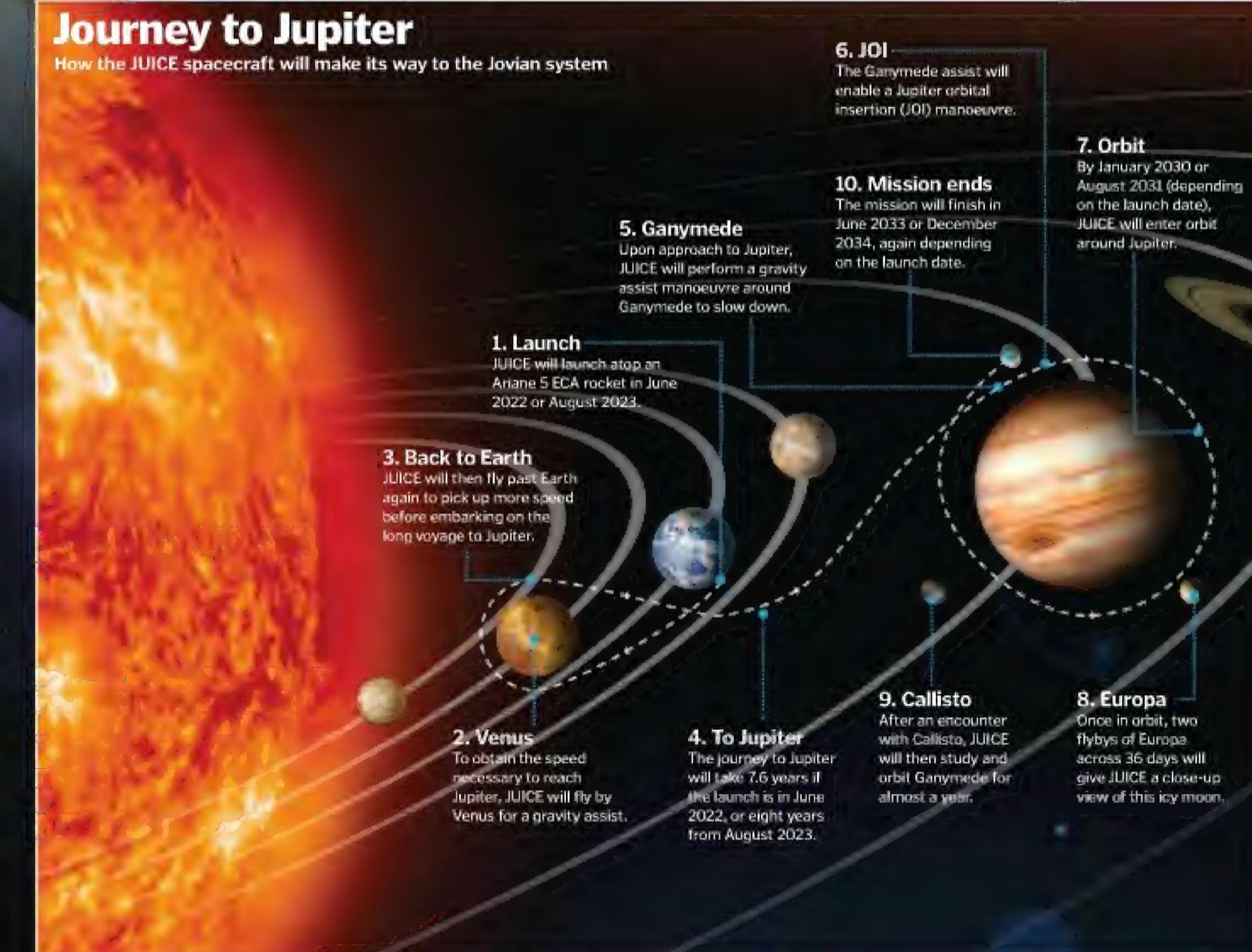
The Guiana Space Centre is a prime launch site for two main reasons. The first is that it is located close to the equator, which means that rockets get an extra speed boost from the rotation of the Earth that they wouldn't get at more northern or southern latitudes. Its second advantage is that it is located in a sparsely populated area. Rockets launch over the Atlantic Ocean, so if for some reason one were to fail it would safely fall into the ocean and not threaten any built-up areas.



ESA's Herschel space telescope was launched on an Ariane 5 rocket from the Guiana Space Centre on 14 May 2009

Journey to Jupiter

How the JUICE spacecraft will make its way to the Jovian system





"This spacecraft will take with it a host of scientific instruments to study the Jovian system like never before"

1973

1979

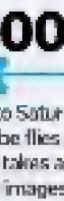
1995

2000

2016

Pioneer 10 becomes the first spacecraft to visit Jupiter when it flies past the gas giant in late-1973.

Voyager 1 makes its closest approach to Jupiter, imaging the planet and some of its moons.



On its way to Saturn the Cassini probe flies past Jupiter and takes about 26,000 images.

NASA's solar-powered Juno probe is expected to enter orbit around Jupiter in July 2016.

DID YOU KNOW? Ganymede is the ninth-largest body in the Solar System – it's even bigger than Mercury!

The focus of JUICE's mission, which will cost around €1 billion (£860 million/\$1.3 billion), will be to examine and characterise three of the four Galilean moons – namely Europa, Ganymede and Callisto. This spacecraft will take with it a host of scientific instruments to study the Jovian system like never before, including high-resolution cameras and spectrometers to analyse the composition of Jupiter's atmosphere and its satellites. The emphasis of the scientific goals will be to provide evidence as to whether the moons – specifically Ganymede and Europa – could be habitable to some form of microbial life either on the surface or in the oceans thought to exist under each moon's icy crust.

The spacecraft will launch on an Ariane 5 rocket in June 2022 to make use of favourable positioning of Jupiter to enable the spacecraft to reach the planet by using gravitational assists from Venus and Earth. A secondary launch date of August 2023 has also been put in place, which means there's a backup if for some reason JUICE is delayed. The spacecraft is powered by a solar array, while multiple thrusters will enable it to orientate itself.

Once at the Jovian system JUICE will spend over three years studying Jupiter and its moons. Aside from the bodies mentioned earlier, the nature and longevity of the mission means that JUICE will be able to study many other interesting objects around Jupiter such as the volcanically active moon Io and some of the smaller natural satellites too.

JUICE will carry 11 scientific experiments that each has a specific purpose. One of the most interesting is an ice-penetrating radar that, by using a method known as sounding, will be able to measure the thickness of the icy crust on moons such as Ganymede and Europa – something that has never been done before – and thus revealing the depth of any subsurface oceans. There's also a proposal to include a Russian-built Ganymede lander with JUICE, which could touch down on the moon and perform surface operations, although this has not been decided on yet.

JUICE is part of the European Space Agency's Cosmic Vision programme – the over-arching name that's been given to all ESA scientific space missions taking place between 2015 and 2025. Barring any problems or delays, JUICE will become one of the highest-profile missions in the Solar System when it launches in the early-2020s, so it's certainly one to watch out for. ☀

Science at Jupiter

JUICE's main objective is to study three of the Galilean moons – Ganymede, Europa and Callisto – with particular emphasis on the former. This will include performing a detailed characterisation of the moons and ascertaining whether they may be hospitable to life. JUICE will also study Jupiter and its atmosphere to help us further understand the gas giant planet.



Callisto

The desolate Callisto is one of the most heavily cratered bodies in the Solar System, but its ancient and inactive surface could hold some of the oldest records from the early Solar System. Callisto, like Ganymede and Europa, may also be concealing an ocean beneath its surface, so JUICE will conduct further studies of the moon to deduce whether or not this is the case by looking for subsurface water reservoirs. JUICE will attempt to map parts of the surface and pin down its physical properties as well.



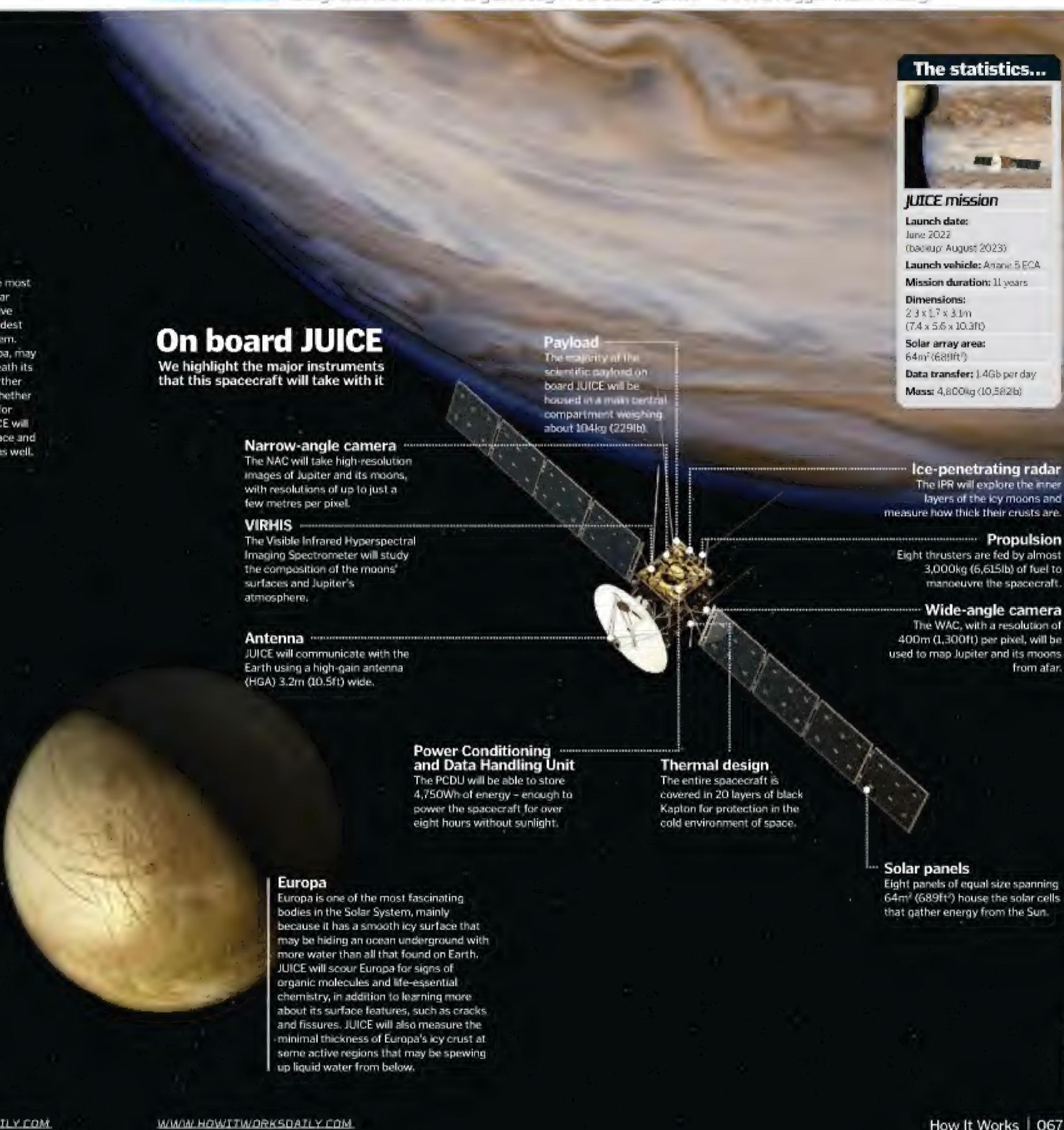
Io

While in the Jovian system JUICE may have a chance to observe the fascinating moon that is Io – the most volcanic place in the Solar System. It has more than 400 known active volcanoes that spew sulphur and other material onto its surface, lending the moon its odd yellow hue. Io's volcanism stems from its eccentric orbit around Jupiter, with the gas giant and its other moons pushing and pulling Io to cause extreme tidal heating at its core.

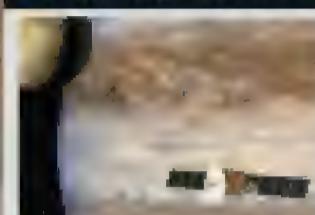


Ganymede

Ganymede is the largest moon in the Solar System, and also one of the most interesting. Like Europa it's believed to have an icy crust with a rocky surface lurking below, while it may also have a magnetic field like Earth's that interacts with the Jovian magnetosphere. JUICE will attempt to reveal more about Ganymede by performing topographical and geological mapping of the surface, in addition to characterising the icy surface and subsurface ocean with the various scientific instruments on board.



The statistics...



JUICE mission

Launch date: June 2022 (backup: August 2023)
Launch vehicle: Ariane 5 ECA
Mission duration: 11 years
Dimensions: 2.3 x 1.7 x 3.1m (7.4 x 5.6 x 10.3ft)
Solar array area: 64m² (680ft²)
Data transfer: 1.4Gb per day
Mass: 4,800kg (10,602lb)

Ice-penetrating radar
The IPR will explore the inner layers of the icy moons and measure how thick their crusts are.

Propulsion
Eight thrusters are fed by almost 3,000kg (6,615lb) of fuel to manoeuvre the spacecraft.

Wide-angle camera
The WAC, with a resolution of 400m (1,300ft) per pixel, will be used to map Jupiter and its moons from afar.

Thermal design
The entire spacecraft is covered in 20 layers of black Kapton for protection in the cold environment of space.

Solar panels
Eight panels of equal size spanning 64m² (680ft²) house the solar cells that gather energy from the Sun.



"In the case of human payloads, these were delivered via an airlock located at the front of the shuttle"

22,753kg

BIGGEST PAYLOAD TO SPACE
The heaviest non-commercial payload ever launched – the Chandra X-ray Observatory – weighed in at 22,753 kilograms (50,161 pounds) on Space Shuttle mission STS-93 in 1999.

DID YOU KNOW? The last Space Shuttle launch – STS-135 – carried a payload of 3,630kg (8,000lb) of supplies

Space Shuttle payload bay

How did this colossus deliver tons of supplies and technology into space?



NASA's Space Shuttle launch vehicles undertook over 130 missions during their lifetime, carrying hundreds of tons of technology into space. It had a refined system for delivering payloads to the intended target – be that simply low-Earth orbit or space stations such as the ISS – following a five-step mission profile.

After liftoff, solid-rocket booster separation, external fuel tank separation and orbital insertion, the in-orbit operations could begin. In the case of human payloads, these were delivered via an airlock located at the front of the shuttle, but when dealing with inanimate cargo, that required accessing the internal storage hold, known as the payload bay. Tech and supplies were accessed by the opening of the shuttle's payload bay doors, which swung open from the top of the spacecraft.

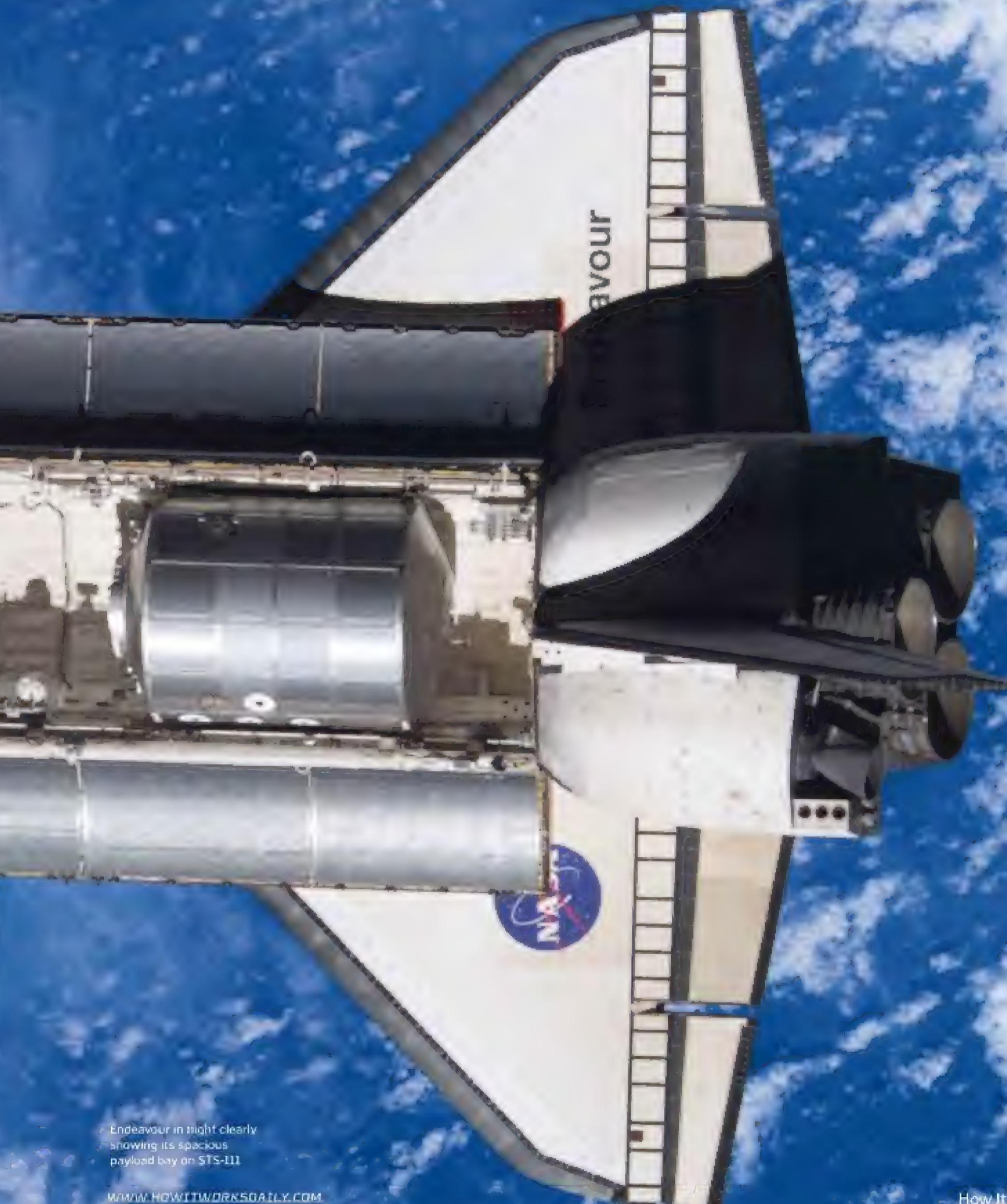
Once the bay doors were open, the resources within could be collected either by an EVA (extravehicular activity, or spacewalk), or using a robotic mechanical arm called Canadarm. This arm, 15.2 metres (50 feet) long and 30 centimetres (12 inches) in diameter, had six degrees of freedom and was specially built to manoeuvre cargo from the bay to their final position on the ISS. Once the payload for a mission had been successfully delivered, the Space Shuttle would then be prepared for re-entry and the return trip to Earth. •



The STS-134 payload is lifted into the rotating service structure on Launch Pad 39A



The Canadarm being used to retrieve cargo from within the Space Shuttle



Endeavour in flight clearly showing its spacious payload bay on STS-111

"The density becomes so great that further fusion reactions release an immense amount of energy"

THE STATS
 TRITON NUMBERS

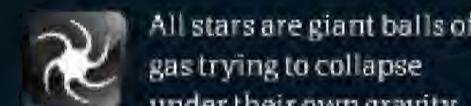
DISCOVERED 1846 GRAVITY 0.779m/s²
 TEMPERATURE 38K VOYAGER 2 VISIT 1989 ORBITAL PERIOD 5.87 days

DIAMETER 2,700km

DID YOU KNOW? Triton is so massive that if it were orbiting the Sun it would be considered a dwarf planet.

How huge stars go supernova

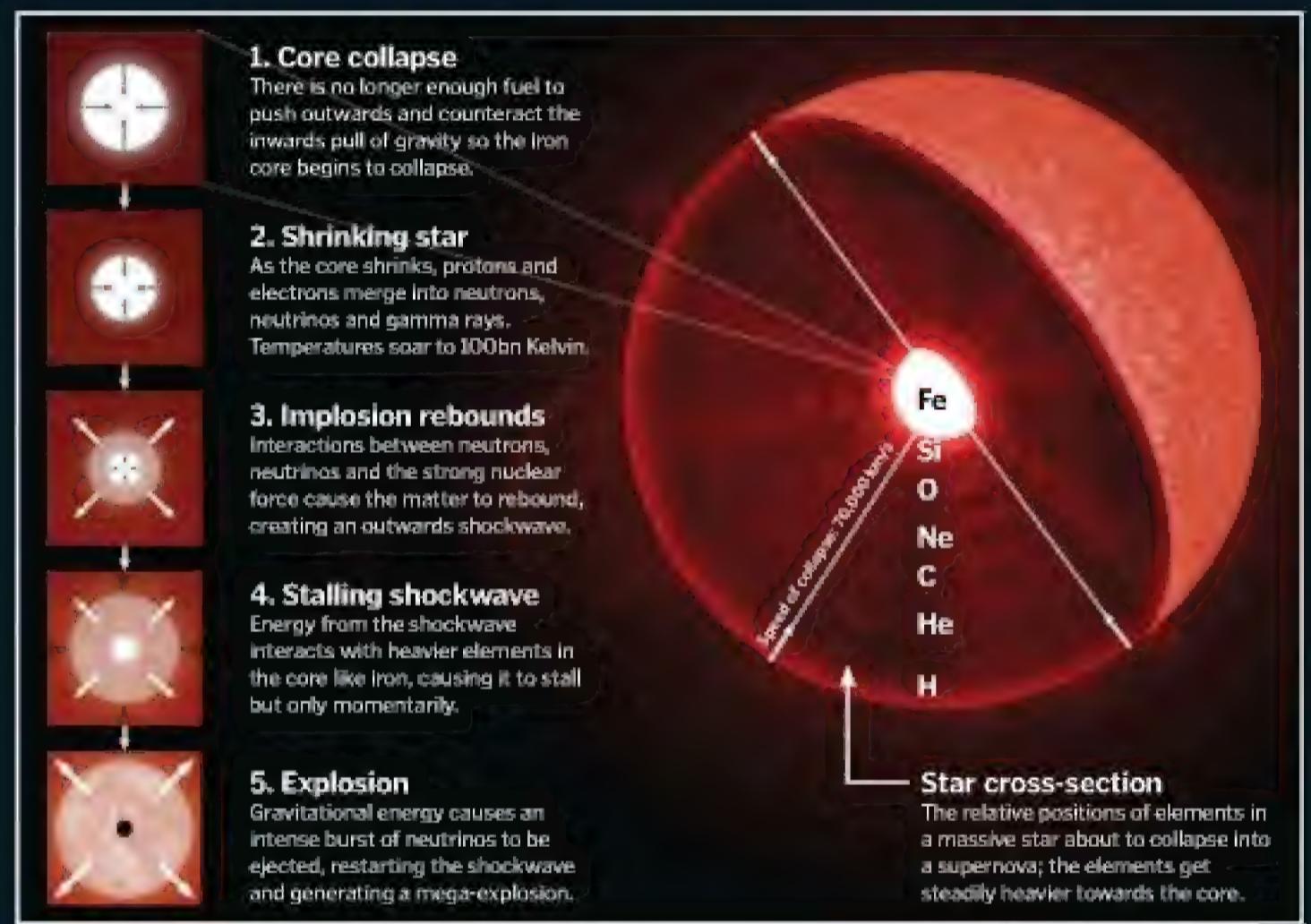
Key events at the end of a massive star's life that lead to a cataclysmic explosion



All stars are giant balls of gas trying to collapse under their own gravity. Pressure caused by the collapse generates nuclear fusion – the fusing together of hydrogen and helium nuclei – giving off enough energy to push outwards, so the star doesn't collapse further.

When massive stars eight times the mass of our Sun run low on fuel, the inwards pull of gravity overcomes this outward force, causing the star to shrink. The density becomes so great that further fusion reactions release an immense amount of energy in a matter of seconds, generating the most explosive event in the universe: a supernova.

A large proportion of the star's material is ejected outwards, while an inwards force of equal magnitude causes the remaining matter to collapse into a neutron star or even a black hole.



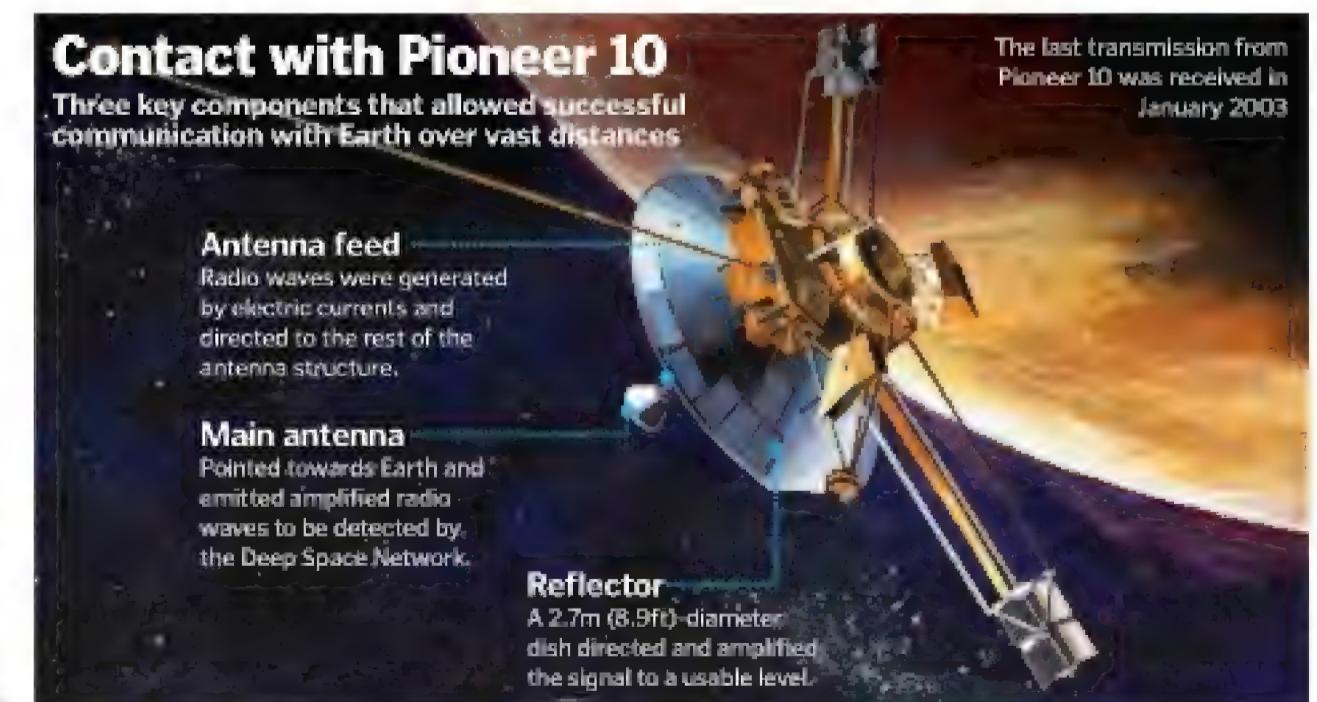
Communicating with space probes

How do scientists keep in touch with deep-space probes like Pioneer 10 and 11?



Communicating with something over 11.2 billion kilometres (7 billion miles) away is no mean feat, and requires a worldwide network of huge radio antennas. Stations in California, Spain and Australia form the Deep Space Network (DSN) – strategically spread out to ensure there will always be one antenna that can point at any space probe.

Likewise, space probes – like Pioneer 10 and 11 launched in the early-Seventies – need antennas to send pictures, weather data and heading information as radio waves. However power constraints mean that space probes can only send very weak signals, which get weaker the farther away they travel. Antennas on the ground have large dishes to capture the signal, yet greater amplification and noise reduction is needed to boost the signal to a readable level.



The backwards moon

Why is Neptune's biggest satellite, Triton, the only large moon in the Solar System to orbit its planet in the opposite direction?



Moons usually orbit in the same direction as their parent planet is spinning. Triton's unique orbit indicates it was not formed in the same region as Neptune. Instead, it is believed that it was captured from the Kuiper Belt, an icy ring at the edges of the Solar System that contains thousands of bodies, including Pluto.

For an object to be captured by a planet, it must lose energy, preventing it from escaping the gravitational field. This often occurs as a result of a collision; however, in the case of Triton, this is thought to be unlikely. Instead, Triton may have originally had a companion, like Pluto's moon Charon. As the pair came close to Neptune, their orbital energies were disrupted, being transferred to Triton's

companion and expelling it from the system, leaving Triton caught in Neptune's orbit.

Triton is very similar in composition to Pluto; it has an icy surface primarily composed of frozen nitrogen, water and carbon dioxide. It is the seventh-largest moon in the Solar System, and is more massive than all of the smaller moons combined. Triton's surface shows evidence of having been melted, and icy volcanoes erupt from the crust, spewing gas and dust about eight kilometres (five miles) up.

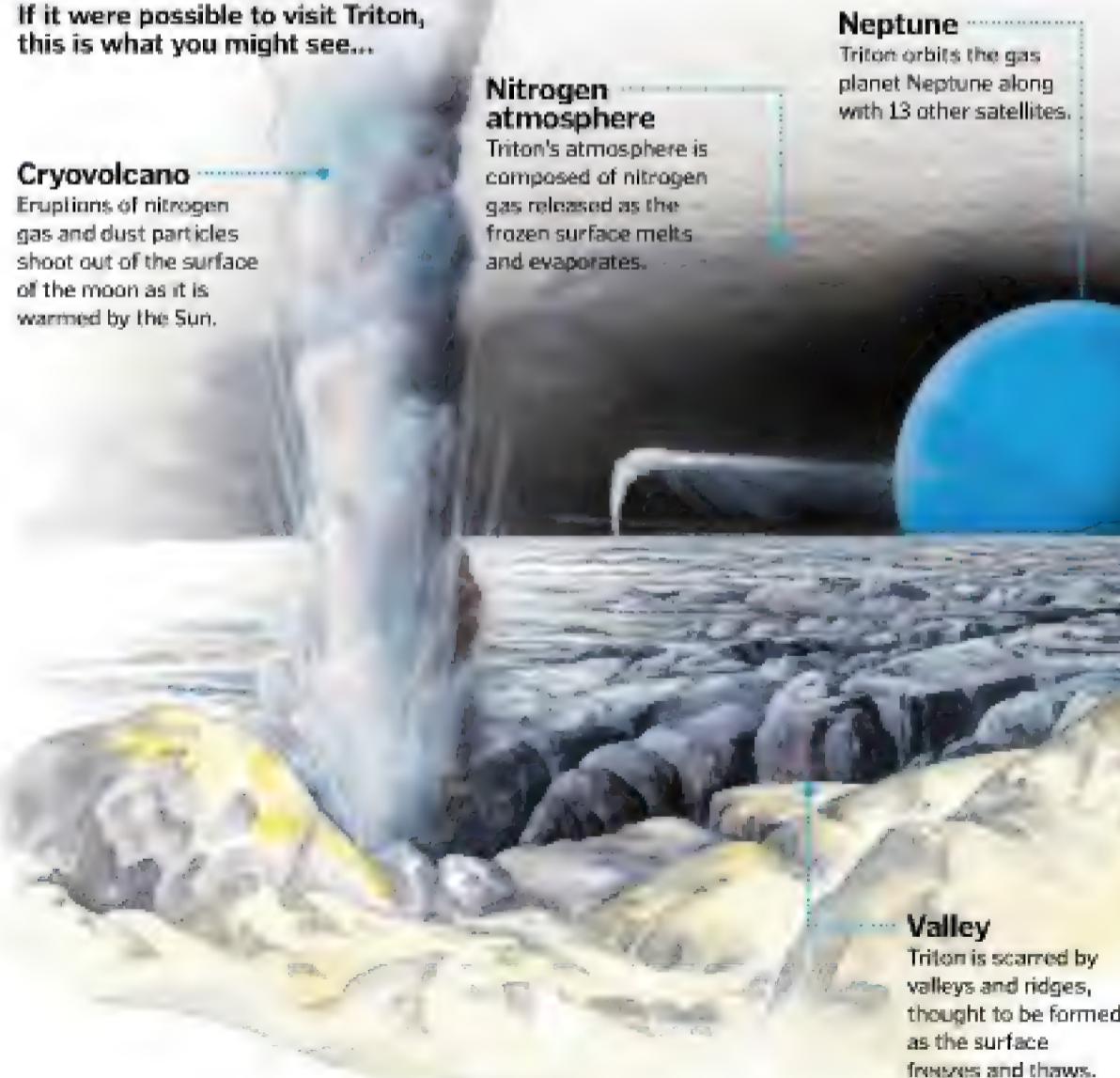
Beneath the crust are a mantle of water and a core of rock and metal. It is possible that the heat generated by radioactive decay in the rocky core is able to keep the mantle molten, producing a liquid ocean below the moon's outer surface, similar to that on Europa.

On the surface

If it were possible to visit Triton, this is what you might see...

Cryovolcano

Eruptions of nitrogen gas and dust particles shoot out of the surface of the moon as it is warmed by the Sun.



Could you spend a day on Triton?

Despite the fact that Triton has a solid, icy surface, it would presently be impossible for a human to step onto the moon. Surface gravity is 12 times weaker than Earth's, and the average temperature is in the region of 38 degrees Kelvin (-235 degrees Celsius/-311 degrees Fahrenheit).

Equally problematic, Triton's atmosphere is very thin. It is composed of nitrogen gas, which is thought to have evaporated from the frozen nitrogen that covers the moon's surface. The atmosphere is so thin that atmospheric pressure is just one-70,000th what it is on Earth.



Neil Armstrong

Discover how a boy with a fascination for aviation went on to be the first man to set foot on the Moon

"Neil Armstrong earned his flight certificate by the age of 16 – before he had even learnt how to drive"



Neil Armstrong was 38 years old when he was chosen to lead Apollo 11

A life's work

A look at the key events in this astronaut's life that took him all the way to the Moon

1930

Nell Alden Armstrong is born in Ohio on 5 August to Stephen Koenig Armstrong and Viola Louise Engel.

1949

Armstrong is called into service during the Korean War, and flies over 75 combat missions.

1955

He graduates with a degree in Aeronautical Engineering from Purdue University.

1955

Armstrong begins work as an experimental test pilot at Edwards Air Force Base.

1956

Janet Elizabeth Shearon and Neil Armstrong marry, and go on to have three children.



Armstrong made a cast of his footprint for display at the Marshall Space Flight Center in 2007



The Apollo 11 crew from left to right, Neil Armstrong, Michael Collins, Buzz Aldrin

Top 5 facts: Neil Armstrong

1 War hero

While flying in the Korean War, Armstrong's F4F Panther was hit by anti-aircraft fire. He collided with a pole and part of the wing was ripped off, but luckily he wasn't injured.

2 Space Scout

As a child, Armstrong was a Boy Scout. On his way to the Moon, he sent a message to the Scouts back on Earth.

3 Hated the limelight

Armstrong stayed out of the public eye after his return from the Moon, refusing to sign autographs and turning down many advertising offers.

4 Awards and honours

Armstrong is one of the most honoured men in history and received several awards in his lifetime, including the Presidential Medal of Freedom – which is the highest civilian accolade in the United States.

5 Frequent flyer

During his time as a test pilot, Armstrong logged over 1,000 hours of flights, and throughout his career flew over 200 different types of aircraft.

In their footsteps...



Chris Hadfield

In March 2013, Chris Hadfield became the first Canadian commander of the ISS. Hadfield describes watching the lunar landing in 1969 as a "watershed moment" and admired Armstrong for his "quiet accomplishment". There was no space programme in Canada when Hadfield was a child, but Armstrong inspired him to pursue his dream.



Sally Ride

An inspiration herself, Sally Ride was the first US woman in space. In the early days of space travel, NASA recruited mostly military pilots for their missions, but as missions became ever-more advanced, the need to take scientists to space became apparent. Physicist Ride was recruited and flew two missions aboard Challenger.

The big idea

In 1969, Neil Armstrong was commander of a three-man mission to the Moon – Apollo 11. Armstrong's famous words, "That's one small step for man, one giant leap for mankind", were not planned until the Lunar Module had touched down. In interviews he later stated that he thought the chances of a successful touchdown were so small that planning what to say in advance was unnecessary.



as the commander for the game-changing Apollo 11 mission heading to the Moon.

Having spent a year learning to pilot a modified version of the Lunar Module on Earth, he and two colleagues departed for the Moon on 16 July 1969. The Lunar Module landed on the surface of the Moon on 20 July and, at 10:56pm EDT, Neil Armstrong became the first man to set foot on an extraterrestrial body, uttering the famous words, "That's one small step for man, one giant leap for mankind". Buzz Aldrin followed him onto the surface 20 minutes later, and the pair then spent over two and a half hours conducting experiments and gathering samples. They also erected a plaque and planted a US flag to commemorate the mission.

On re-entering the Lunar Module, Armstrong discovered that the ignition switch had been broken by their spacesuits, and had to restart the craft using a pen to push the circuit breaker.

After splashing down in the Pacific Ocean, the crew were quarantined for 21 days to safeguard against any infection that might have been contracted in space. They then spent 45 days on a tour of the world to celebrate one of mankind's greatest-ever achievements.

After the Apollo 11 mission, Armstrong retired from spaceflight and took a teaching position at the University of Cincinnati, OH. He continued to work for NASA as well though, and assisted in the investigations following the Apollo 13 and Challenger disasters.



Armstrong working on the Lunar Module on the surface of the Moon



1962

After joining the astronaut programme he moves to Houston, TX, with his family.



1966

As the command pilot for the Gemini 8 mission, Armstrong participates in the first docking of two vehicles in space.



1969

On 20 July, Neil Armstrong becomes the first man to ever walk on the Moon.



2012

Neil Armstrong dies due to complications following heart surgery. His family request that people 'wink at the Moon' in his honour.

Ankylosaurus

A club-wielding brute of a creature, this tough dino had the power to break bones

Ankylosaurus was one of the largest ankylosaurs, a genus of armoured dinosaurs that lived throughout North America between 75 and 65.5 million years ago. Famous for both its brutal tail-mounted club and its immense bone plate armour, the Ankylosaurus was a defensive titan, capable of fending off rivals many times its size.

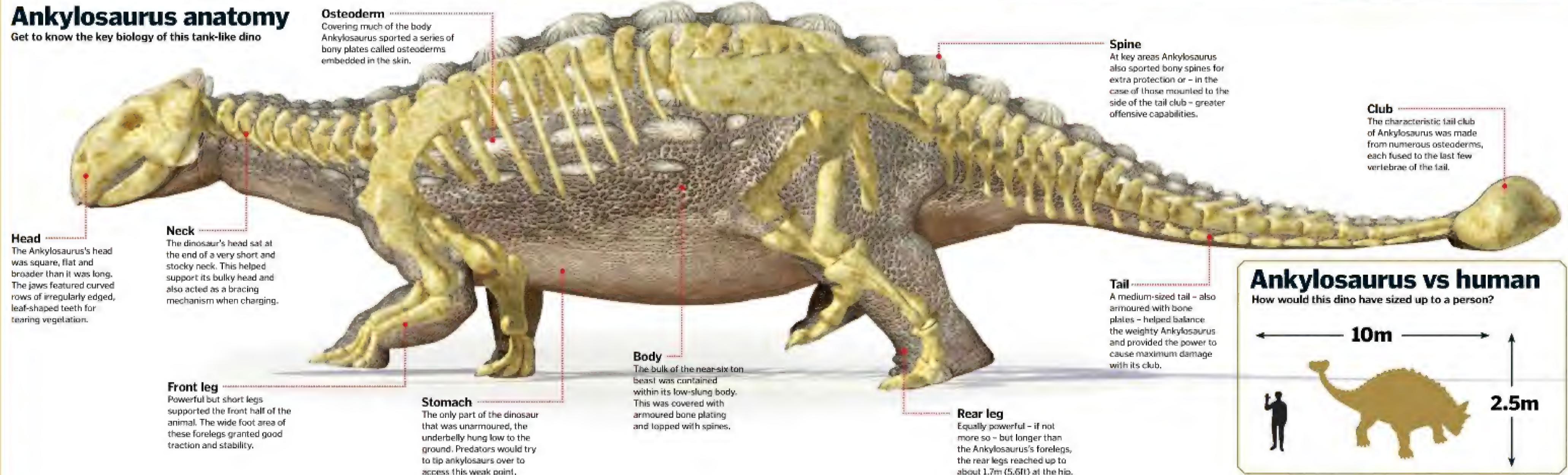
Ankylosaurus's focus on defence was born out of its herbivorous nature, with its entire body geared towards the consumption of foliage. From its low-slung body, rows of leaf-shaped cropping teeth, short front legs, wide feet and cavernous stomach, the Ankylosaurus was the consummate browser,

devouring vegetation whole with little shredding or chewing. Indeed, studies have indicated that the skull and jaw of the Ankylosaurus were structurally tougher than many similar, contemporary dinosaurs.

In fact, evidence suggests that Ankylosaurus – and ankylosaurs in general – were adept survivors. But despite their impressive armour, weaponry and sustainable diet, they could not cope with the Cretaceous-Tertiary extinction event that wiped out all terrestrial dinosaurs approximately 65.5 million years ago. Only a few fossils of this prehistoric herbivore have been excavated to date – most coming from the Hell Creek Formation in Montana, USA. ◉

Ankylosaurus anatomy

Get to know the key biology of this tank-like dino



"Paper documents were vulnerable to moisture, but placed on film they became all but impervious to it"

STRANGE BUT TRUE CASTLE IN THE SKY

What is Himeji Castle believed to resemble?
A A bird B A plane C Superman



Answer:
 Owing to its distinctive white plaster walls and the fact that the shape of the complex is said to resemble a bird taking flight, Himeji Castle is also often known by the names Shirasagi-jo (White Heron Castle) or Hakuro-jo (White Egret Castle).

DID YOU KNOW? During wartime, Japanese builders resorted to smashing up gravestones for construction materials.

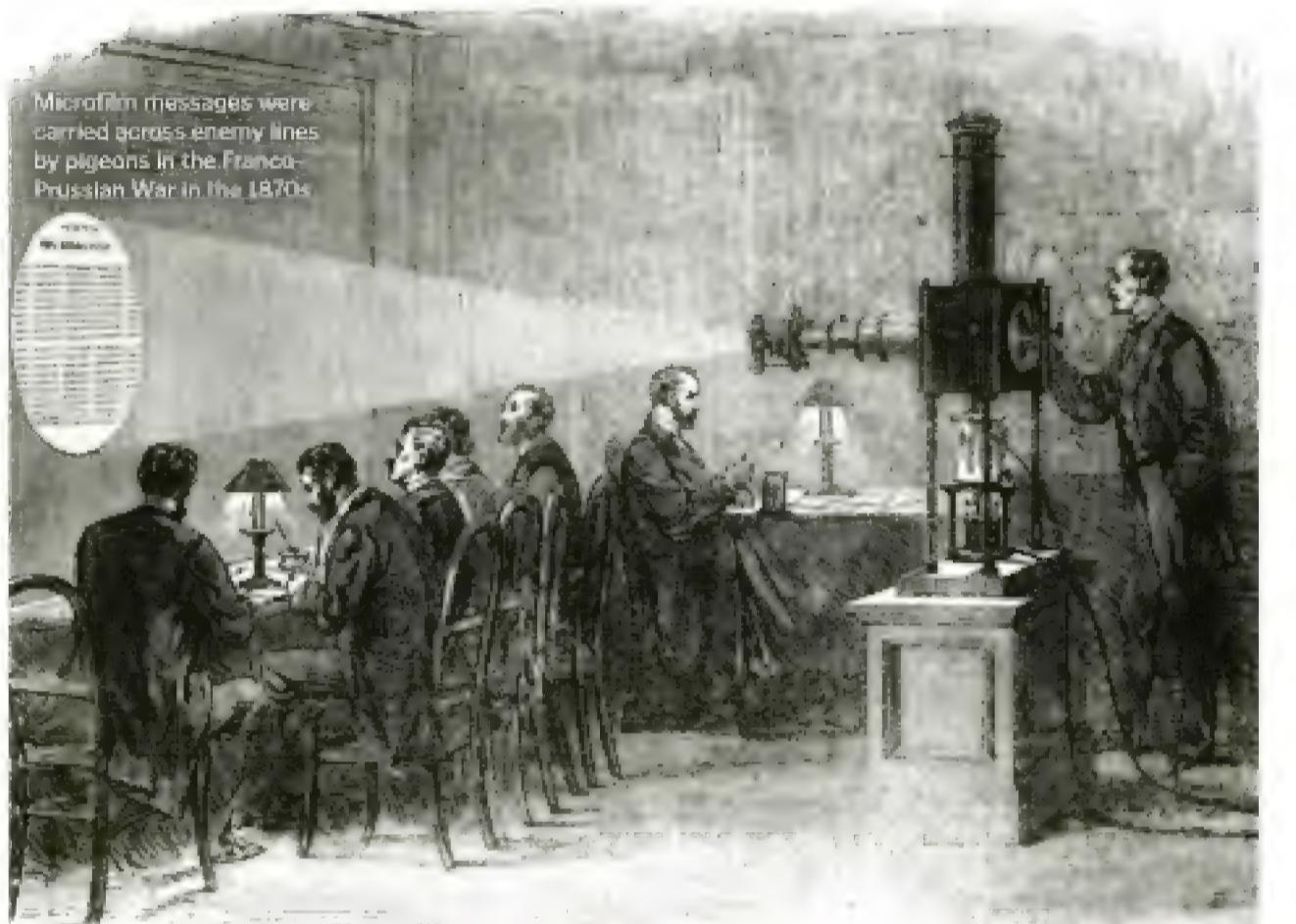
How did microfilm work?

The small-scale media storage that served as the perfect medium for covert messages

 Microfilm was a physical storage media – typically 16-millimetre (0.6-inch) or 35-millimetre (1.4-inch) film – upon which images were reduced in size to a fraction of their former selves. This allowed documents, photographs and video footage to be shrunk, copied and stored for both secrecy and greater longevity. For example, historical paper documents were very vulnerable to moisture, but when imaged and placed on film they became all but impervious to it.

Often batches of documents were placed on one large sheet of microfilm with a readable code on top referred to as a microfiche – the code enabled the documents to be identified immediately. Viewing the stored image was achieved with a slide/film-based projection system (as pictured) that was similar to the overhead projectors we use today.

While microfilm is still used in select applications, the invention of the computer and virtual media has largely left it obsolete, with documents, images and films now copied and backed up on discs or cloud storage.



How pottery was made

The potter's wheel turned the way we produce ceramics on its head



Tools
 While pots are moulded with the hands, a number of small tools help the potter make incisions and add decoration.

Modelling wheel
 The potter shapes the clay material on this plate, which rotates at high speed while they model the object.

Wheel shaft
 Both wheels are connected through the centre of the wooden frame by a metal shaft.

Kick wheel
 The potter kicks this wheel to start it rotating. It acts as a flywheel, storing energy and forcing the connected modelling plate to spin at high speed.

Frame
 The wooden frame provides support for both the wheels and a surface for the potter to work on.

 The potter's wheel enabled us to easily create round ceramic wares such as pots and gourds. The machine worked by supplying the potter with a rotating circular platform upon which, via hand moulding, clay could be shaped as desired. The rotation was provided by a large kick wheel, which once set in motion – the potter literally kicked it, hence the name – supplied energy to a smaller modelling wheel, which sat above on a metal shaft. As the kick wheel was much bigger than the modelling wheel, it acted as a flywheel, storing rotational energy that could be used to power the modelling plate, which due to its smaller circumference, spun at a greater speed.

Thanks to its ease of use, the potter's wheel remained the method of choice for making pottery for many millennia, eventually evolving to be driven by a motor.

Inside a Japanese castle

We find out how Himeji Castle – a 17th-century fortification – has stood firm despite several centuries of conflict and natural disasters



Built on a hill 45 metres (150 feet) above sea level in southern-central Japan, Himeji Castle has survived innumerable feudal battles, sieges, earthquakes and even a WWII bombing. While today it's famed as Japan's largest castle, construction of the original site began in 1333 with the building of a small fort. The fort wasn't turned into a castle stronghold until nearly 250 years later, towards the end of the civil war era. The addition of three moats and dozens of extra buildings – including three large towers and a huge, six-storey main keep, or tenshu – saw the striking white complex become one of the greatest Japanese castles ever built.

Before they could even think about breaching the defences, the enemy would first have to navigate a frustrating maze of steep, snaking paths laid out around the castle walls. The physically demanding paths that seemed to lead directly to the main keep – but which often led instead to a dead-end – would disorientate and tire invaders. And even if they made it

As is typical of traditional Japanese architecture, Himeji Castle is an elevated wooden structure featuring ornate tiling and embellishment. As well as gates, walls and other protective fixtures, Himeji and many other castles were equipped with a number of defensive devices to stall advancing foes.

As is typical of traditional Japanese architecture, Himeji Castle is an elevated wooden structure featuring ornate tiling and embellishment. As well as gates, walls and other protective fixtures, Himeji and many other castles were equipped with a number of defensive devices to stall advancing foes.

beyond the perimeter, the home team would then deploy an ingenious bevy of traps designed to outwit and injure the incoming aggressors, including conduits down which they would pour boiling oil or water.

Japan's best-preserved 17th-century castle, Himeji became a UNESCO World Heritage Site in 1993, which is quite remarkable considering what the region has endured, from earthquakes to attacks by US B-29 bombers. Of course, since the demolition of the original 1333 fort, the castle has been rebuilt and remodelled by various rulers and architects, but what's interesting is that neither nature nor conflict has ever managed to get the better of Himeji.

Tour of Himeji Castle

Explore this impressive Japanese castle to find out how it stayed safe under attack

Main keep

Located in a large courtyard the main keep, or tenshu, is the highest tower in the complex. Due to its vulnerable wooden construction, it's covered with thick, fireproof plaster.

Rock chute

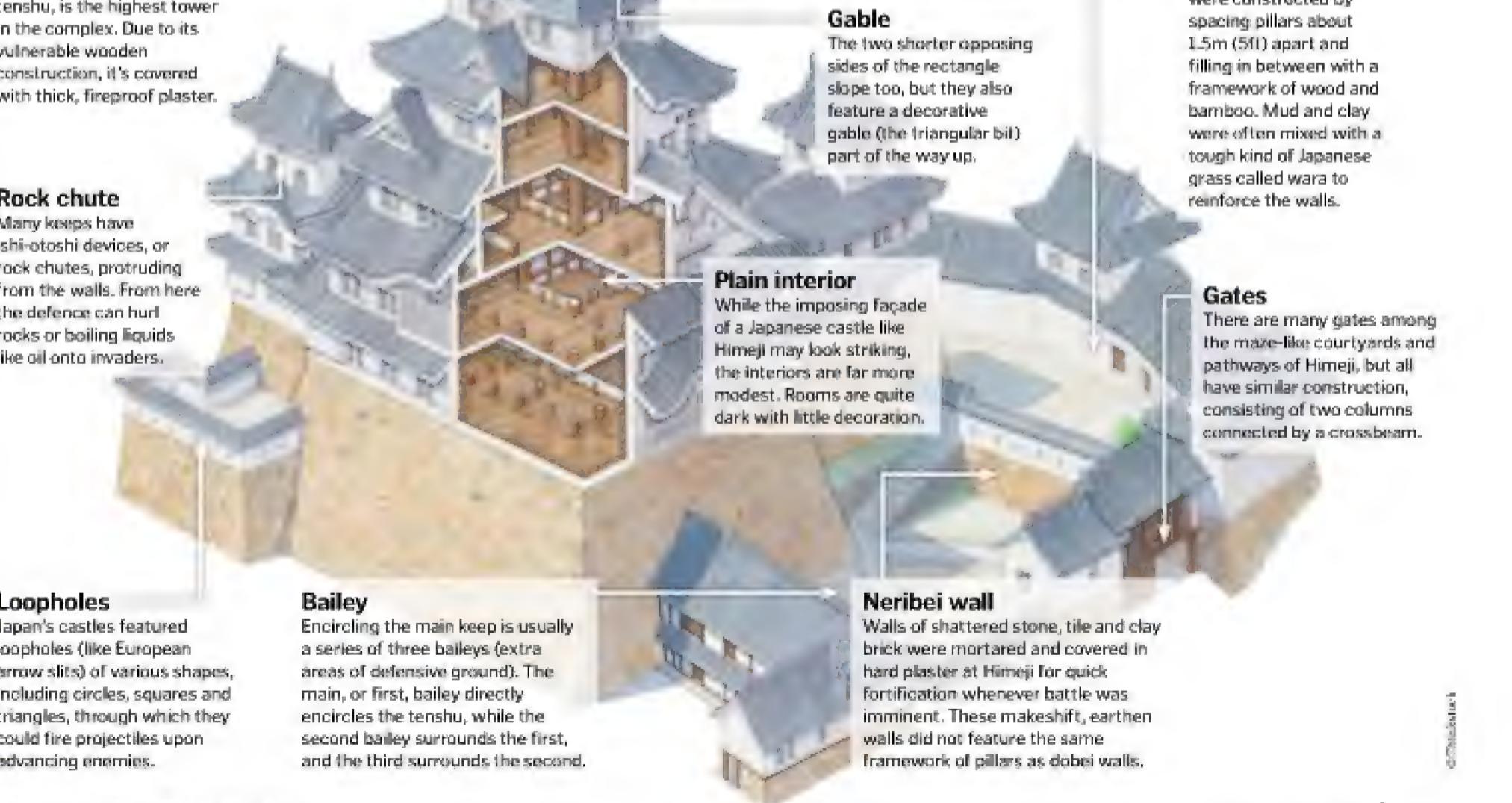
Many keeps have ishi-otoshi devices, or rock chutes, protruding from the walls. From here the defence can hurl rocks or boiling liquids like oil onto invaders.

Loopholes

Japan's castles featured loopholes (like European arrow slits) of various shapes, including circles, squares and triangles, through which they could fire projectiles upon advancing enemies.

Bailey

Encircling the main keep is usually a series of three baileys (extra areas of defensive ground). The main, or first, bailey directly encircles the tenshu, while the second bailey surrounds the first, and the third surrounds the second.



"The Mona Lisa is kept in a clear container with controlled humidity, temperature and light levels"

5 TOP FACTS

THE MONA LISA

What a steal

1 The Mona Lisa was actually stolen from the Louvre museum in Paris on 21 August 1911. However the work of art was later recovered in Italy and returned in 1913.

Bulletproof

2 Today the Mona Lisa is displayed behind a bulletproof glass enclosure to prevent damage by vandals, which has been attempted a number of times over the years.

Saving face

3 As the Mona Lisa is over 500 years old it has gone through a number of renovation and conservation programmes - the latest seeing it lit by a 20-watt LED lamp.

Popular lady

4 In its current position in the Louvre, the Mona Lisa is viewed by over 6 million people per year. As a result it's one of the most viewed paintings on the planet.

Worth millions

5 In 1962 it was assessed at £64.5 million (\$100 million). In 2013 it's worth over £489.5 million (\$750 million), easily making it the world's most expensive painting.

DID YOU KNOW? Infrared images of the painting have revealed Da Vinci's original sketch marks beneath the paint/varnish

Preserving the Mona Lisa

What techniques are being used to maintain the world's most well-known painting?

The *Mona Lisa* is an oil painting on a poplar wood panel by Leonardo da Vinci. Believed to be a half-length portrait of Lisa del Giocondo (maiden name Gherardini) - the little-known wife of a Florentine cloth and silk merchant - it's considered the most famous painting on Earth, with millions viewing it every year at the Louvre museum in Paris, France.

As the *Mona Lisa* is over 500 years old, an intensive conservation effort is ongoing to preserve it. This conservation is split into two main areas: frame rectification and painting restoration. The frame is the most altered part of the *Mona Lisa* to date, with the original poplar frame warping to the extent that by the start of the 20th century, a crack had developed. This crack was secured by installing two butterfly-shaped walnut braces into the poplar panel and then later a flexible oak frame and pair of cross braces. Today this

physical manipulation is partnered with a closely monitored environment, with the *Mona Lisa* kept in a clear container with controlled humidity, temperature and light levels.

Restoration of the painting itself has gone on for centuries, having first received a wash and new coat of varnish back in 1809. This involved the painting being cleaned with spirits, having specific colours touched up and then being varnished. Following its theft and return in the early 20th century, the painting was worked on once more, with a number of scratches filled in with watercolour.

Finally, following an attack on the painting by vandals in 1956 which caused damage to the left elbow of the figure, this was also repainted with watercolours. Today, work continues on the *Mona Lisa* to restore much of the colour to the enigmatic portrait, with the wash carried out in 1809 now believed to have removed the top layer of paint. *



BRAIN DUMP

Because enquiring minds need to know...



Why do we yawn and is it contagious?

Francesca

■ Nobody is 100 per cent certain why humans yawn, but it definitely is contagious: in one experiment half of the people yawned while watching a video of others yawning. A common theory is that the influx of oxygen from a good yawn revives us by getting rid of excess carbon dioxide in our blood – although some research is now refuting this idea. Instead, we may yawn simply to stretch our tongue and throat muscles, as well as to communicate boredom or tiredness to our peers. One recent study even suggested that yawning may help to regulate brain temperature by exposing the roof of the mouth to cooler air – a bit like a heat sink. AC

Meet the experts...



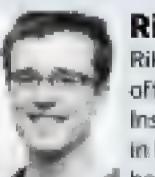
Luis Villazon

Luis has a degree in zoology and another in real-time computing. He's been writing about science and technology since before the web. His science-fiction novel, *A Jar Of Wasps*, is published by Anarchy Books.



Giles Sparrow

Giles studied Astronomy at UCL and Science Communication at Imperial College, before embarking on a career in space writing. His latest book, published by Quercus, is *The Universe: In 100 Key Discoveries*.



Rik Sargent

Rik is an outreach officer at the Institute of Physics in London, where he works on a variety of projects aimed at bringing physics to the public. His favourite part of the job is what he calls 'physics busking'.



Alexandra Cheung

With degrees from the University of Nottingham and Imperial College, Alex has worked at many a prestigious institution including CERN, London's Science Museum and the Institute of Physics.



Michael Simpson

Michael has a doctorate in moss as well as teaching awards from the University of Alberta. While not working as a botanist or environmental consultant, he writes for magazines and online.

Want answers?

Send your questions to...

How It Works magazine @HowItWorksMag
howitworks@imagine-publishing.co.uk

Why we yawn is not yet completely understood, but it could have evolved to stretch facial muscles or as a means of communication



Who invented the tea ceremony?

Lizzie Stokes

■ No one person is credited for inventing the Japanese tea ceremony but several historical groups are thought to have contributed to its development. The ceremony has links with Zen Buddhism, which was founded in Japan near the end of the 12th century. Tea became part of Buddhist rituals and is still associated with tranquillity and harmony today. Tea also became popular with samurai warriors and nobles, who made it the centre of a party game. They were considered celebrities in their day so their appreciation of tea might have encouraged other people to adopt the drink, along with the rituals associated with it. MS

Can we tame tigers?

Vivienne Jones

■ Not in the way you might tame a dog or break in a horse. Dogs and horses have been domesticated for millennia and selective breeding has gradually favoured the genes that make them more friendly. Tigers – even raised from a cub – retain all their predatory instincts. In Thailand, 'tame' tigers live in a monastery, side by side with the monks and tourists, but it's a precarious balance. Roy Horn of the entertainment double act Siegfried & Roy was critically injured in 2003 when the tiger he had performed with for six years bit him. LV



How much honey does a bee make in its lifetime?

Ben

■ Less than a gram. Most worker bees only live for around six weeks in the summer and they can only go and forage for nectar on days when the air temperature is above ten degrees Celsius (50 degrees Fahrenheit). A group of about 12 bees in their lifetime will produce a teaspoon of honey between them. Bees use their honey as an energy source for the hive. Depending on the weather, a hive might use over 20 kilograms (44 pounds) of honey over a single winter. LV

How do you know if berries are poisonous?

Ryan Mann

■ There aren't really any distinctive features we can use to reliably distinguish berries that are poisonous so your best bet is to build up a thorough knowledge of plants or a good guide. Some people advise against eating berries that are white or yellow, or that grow on vines, because they say these are typically bad for you. Most purple, blue or black berries, however, are said to be okay. Yet grapes grow on vines while deadly nightshade berries can appear purplish-black and are highly toxic. The best rule is not to eat the fruit of any wild plant unless you know for sure that it's safe. MS



Which is the planet's most noisy creature? Find out on page 82

5-SECOND FACTS

The brain can hold thousands of gigabytes of data

If each of our brain's neurons is equivalent to a 'bit' of computer memory, then the overall storage capacity may be around ten gigabytes. But in reality our brains are wired up completely different from computers, with many trillions of connections between individual neurons. This means that the brain's capacity could be many terabytes.



Even deserts get snow

It can indeed snow in the desert. Deserts are not defined by how warm they are, but by how little rainfall they receive. Indeed, Earth's largest desert is Antarctica – the coldest, driest and windiest continent on the planet – where heavy snow is quite common.



Want answers?

Send your questions to...

How It Works magazine @HowItWorksMag
howitworks@imagine-publishing.co.uk

5-SECOND FACTS

Flour can be explosive

Like all starches, flour is flammable, but it's only liable to explode when it's suspended in the air, which is why mills and bakeries have to be particularly careful. Surrounded by oxygen, each tiny particle of flour burns almost instantly, igniting the particles around it and allowing the flame to propagate very rapidly to generate an explosion.



Human heads may have once been used to play football

The oldest leather football in existence was unearthed at Stirling Castle in Scotland and dates back to the early 1500s. Centuries before that, however, people were kicking balls that are believed to have been made of animal bladders, skulls or even human heads. More familiar vulcanised rubber footballs were only introduced in the 19th century.

They might be small, but pistol shrimps certainly know how to make themselves heard...



Which is the loudest animal?

Alex Wells

It's the tiger pistol shrimp. The pistol shrimp has one supersized claw that can be cocked open. When 'fired' the claw snaps shut with such speed that a jet of water is fired out at 97 kilometres (60 miles) per hour. The low-pressure wake creates a cavitation bubble of steam that explodes outwards and then almost instantly collapses again. The collapsing bubble is what generates the sound, which can be up to 218

decibels. The sound is used partly for communication, but its main purpose is as a weapon. The shockwave is loud enough to stun fish and even shatter glass. Because it is very high frequency, the shrimp's click doesn't reach very far. The loudest sound used purely for communication, meanwhile, is made by the blue whale, which sends 188-decibel whistles that can be heard 800 kilometres (500 miles) away! LV

What percentage of stars go supernova?

Traci Watson

We can't be specific, but it's without a doubt much less than one per cent. Stars that end their lives in supernova explosions must have at least eight times the mass of the Sun, so that they blow up into a supergiant star and then violently collapse, instead of gently shedding their outer layers and fizzling out like smaller stars do. The reason we can't be sure of a percentage is partly because we don't fully understand how such massive stars form and develop through their lives (sometimes in ways that stop them becoming supernovas), and partly because we've only a vague idea of the quantity of much fainter and lower-mass stars that massively outnumber them in the universe. GS



Why are raccoons invading cities more and more?

James Cooper

It's the same reason humans move to the cities: life there is easier. Raccoons are omnivores and scavengers and they find it much easier to grab discarded food in a dustbin than to catch it in the wild. There are also fewer predators in the city. Raccoons are mostly nocturnal and the only animals that would pose a serious threat - dogs - are generally tucked up indoors or chained in the garden at night. Raccoons are very intelligent, can wriggle into tight spaces and have nimble front paws for undoing latches and opening containers. Toronto now has 50 times more raccoons than the surrounding countryside. LV

What mechanisms support aeroplane wings on the ground?

R Hickman

Wings can be held up by wires or braces on the fuselage and they are also supported by their internal structure. Components that are concealed under the aluminium or composite wing casing include ribs and stringers. The former run parallel to the fuselage and are attached at regular intervals along the wing. The latter run along the length of the wing and connect the ribs. Support is also provided by the spar, which runs parallel to the stringers. An aircraft's fuel is sometimes stored between the ribs and this too can lend more rigidity to the wings. MS



Does electricity ever weigh anything?

Samuel Mycroft

The term electricity includes several different phenomena, but none of these have any weight. To weigh something (that is, to experience the Earth's gravitational pull), an object needs mass. An electric current is created when charged particles move - eg electrons in a copper wire. While these electrons have a tiny amount of mass, they exist in the wire whether or not a current is applied, so the wire's mass doesn't change. The electric force (which causes particles with the

same charge to repel each other, for instance) has no weight as forces don't have mass. The only electric phenomenon which might arguably weigh something is the buildup of a static charge, when an object gains excess electrons. In this case, the extra electrons would add to the object's mass, but the weight difference would be nominal. AC



How much gold is in the world?

Sarah Blain

According to the annual world gold survey by Thomson Reuters, the total amount of gold mined in the history of the world is 171,300 tons - enough to fill a cube with 20.7-metre (68-foot) sides. But opinions differ, mainly because experts can't agree on how much was mined by ancient civilisations, and how much is hidden in the world's bank vaults. So it might be a little less, or a lot more; the Gold Standard Institute estimates there may be as much as 2.5 million tons hidden away out there! On top of that, the US Geological Survey estimates there is about 52,000 tons to still be profitably mined, with huge quantities locked deep within the Earth's interior. GS



How fast is it possible to go?

Jason Garside

The absolute speed limit of the universe is the speed at which light travels in the vacuum of space - 299,792 kilometres (186,282 miles) per second, or 'c'. Nothing can go faster than this as doing so would enable it to violate the basic laws of cause and effect. Einstein's special theory of relativity explains the effect this has on the laws of physics - eg if you had a spaceship

that was powerful enough to travel close to c, you'd find accelerating those last few per cent got harder and harder, as the craft got heavier and heavier. No object with mass can ever reach itself - light can only travel so fast as it is massless. That said, light travels more slowly when it passes through materials such as water and glass, hence why it bends, or refracts. GS

Where did Chinese dragons originate? Find out on page 84



Do metals fuse together in space?

David Perez

■ In theory, yes – it's an effect called 'cold welding' by which the metallic bonds that hold atoms together in each object effectively 'bridge the gap' between them to create a single solid object. In practice, this rarely happens on Earth because most metals form a protective oxide layer where their surface is exposed to the atmosphere. Slight bumps and irregularities in metallic surfaces also prevent this from happening. Even when metals are taken into space, the oxide layer remains – but, of course, if you deliberately polished it off then, yes, the two metals would fuse together, and that's something satellite and spacecraft designers need to bear in mind. GS

5-SECOND FACTS

Saturn is not the only planet with rings

While Saturn's rings are something of an iconic feature, the three other gas giants – Jupiter, Uranus and Neptune – also have their own set. The rings consist of tiny particles of cosmic dust, resulting from collisions and leftover matter that didn't coalesce, held in place by the large bodies' immense gravity.

A polar bear would beat a brown bear

The common brown bear has longer claws than a polar bear, but it's smaller on average. Polar bears also have up to ten centimetres (four inches) of blubber underneath their skin which acts as good armour. Polar bears and brown bears very rarely fight in the wild though, and actually sometimes interbreed.



Why do Chinese dragons resemble snakes?

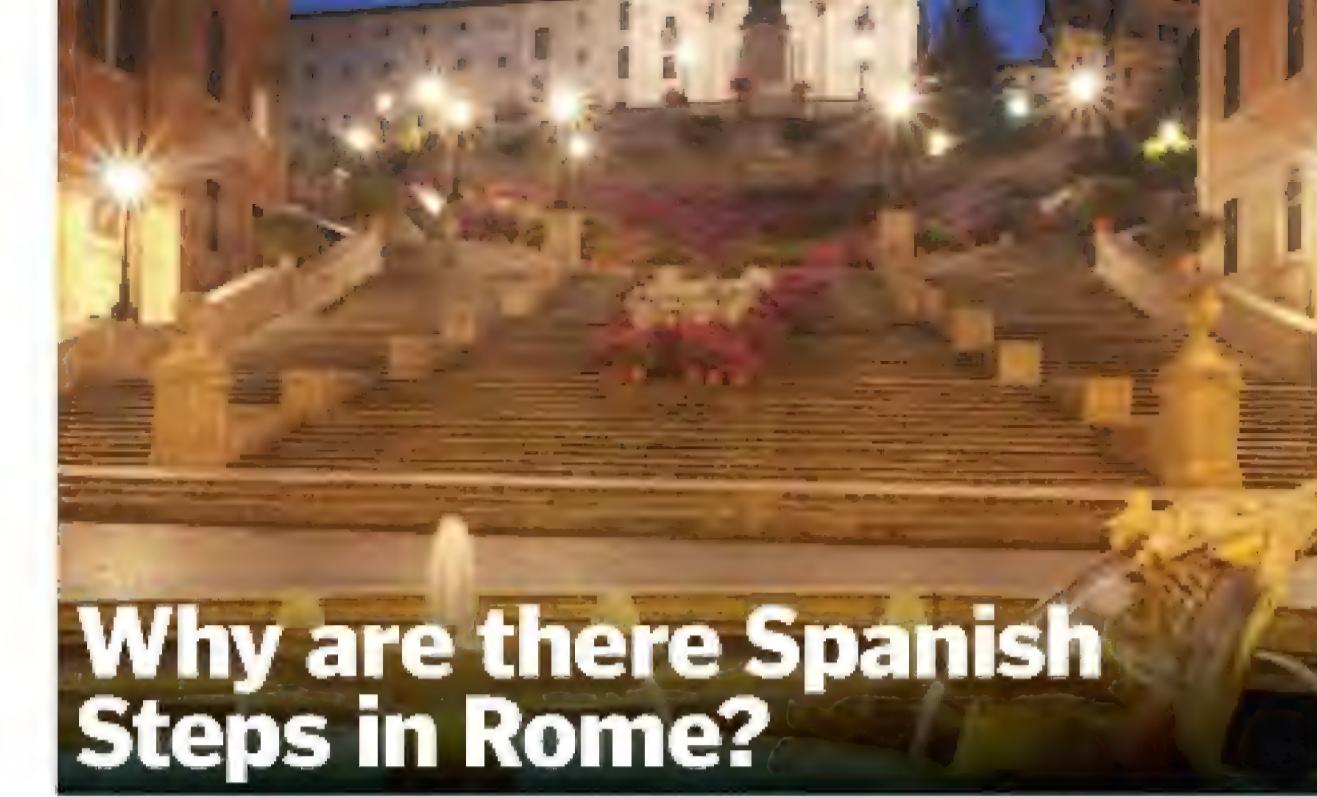
Jessica

■ Mythical snake-like dragons date back to artefacts discovered in north-east China as early as 5000 BCE, but it is not known why they resemble snakes. The earliest depictions of dragons were called pig dragons – small jade sculptures featuring a pig's head with a coiled body. Early versions looked more like a foetus, with the longer serpentine body becoming popular later. In Chinese culture, dragons are synonymous with water and are said to be the

Why is beeswax perfect for candles?

Melissa Davidson

■ Beeswax is solid at room temperature but melts easily and burns slowly, producing very little smoke and emitting a sweet smell. These qualities make it ideal for candle-making although whether or not it is the best material remains subjective. Early candles were made from tallow, processed from animal fat. Tallow candles smelled unpleasant and burned quickly, so beeswax offered big benefits over these. Nowadays, there are many alternatives to beeswax. Most candles are made from paraffin wax, which is odourless, clean and cheap, but other materials such as soybean wax are also popular. AC

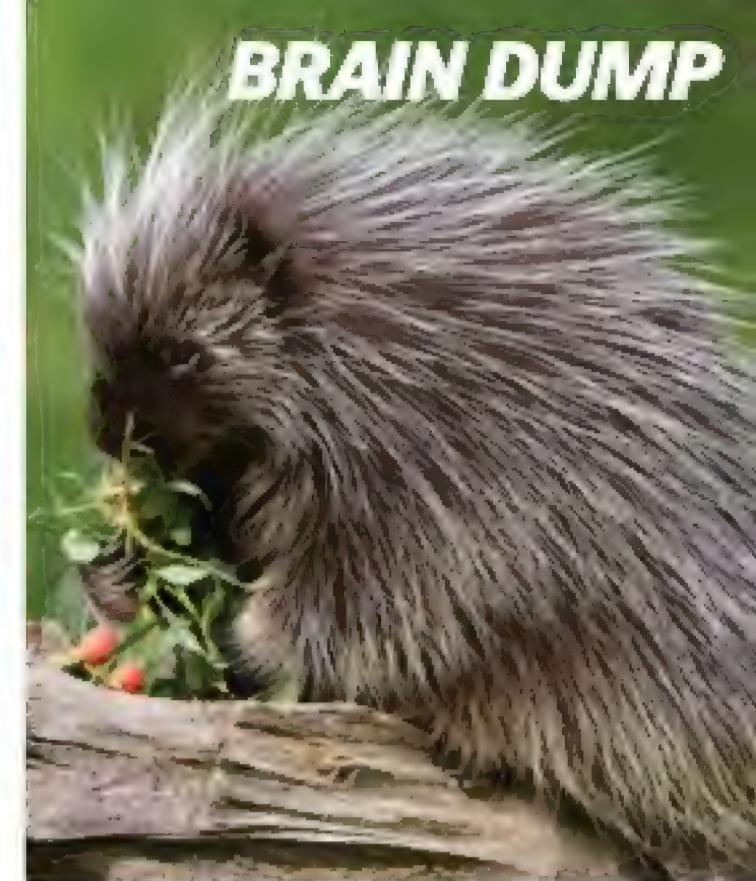


Why are there Spanish Steps in Rome?

Nathan Moore

■ The Spanish Steps, or Scalinata della Trinità dei Monti, link Piazza di Spagna (Spanish Square) with the French church Trinità dei Monti. The Spanish connection comes from the presence in the piazza of the Spanish Embassy to the Holy See (Vatican City). Construction of the stairway began in 1723 and took several years to complete. It was designed by an Italian architect, Francesco de Sanctis, and funded by

money bequeathed posthumously by a French diplomat, Étienne Gueffier. The pathway formed by the steps between the church above and the square below was a symbol of improved co-operation between France and Spain. They were originally named after Trinità dei Monti but that was later superseded. The Spanish Steps are now one of the most popular – and crowded – tourist destinations in Rome. MS



Can porcupines float on water?

Sam Gunn

■ Porcupines are buoyant, thanks in part to the hollow structure of their quills. These sharp spines are solid at the base and tip but mostly hollow in the middle, with a light spongy material (the quill medulla) sealed off inside. This helps porcupines float, but although North American, crested and brush-tailed porcupines are keen swimmers, not all porcupine species are fond of water. Porcupine quills are even sometimes used by fishermen as floats. The main function of quills, though, is for defence. North American porcupines have up to 30,000 quills each measuring around ten centimetres (four inches) long; if a predator gets too close the barbed tips snag into their skin. AC



Why does cooking bacon smell so good?

Lucy P

■ Bacon's mouth-watering smell comes from the meat's amino acids and sugars reacting to heat. Known as the Maillard reaction, the process releases hundreds of compounds associated with desirable aromas and flavours, resulting in a complex assault on our senses. Our brains have evolved to recognise these smells as good, presumably due to the survival advantage that heating food had for our ancestors. The Maillard reaction also happens when you toast bread or roast coffee beans, although different compounds are given off. Some of the compounds have similar characteristics and are often described by food scientists as nutty, smoky and caramel-like. RS

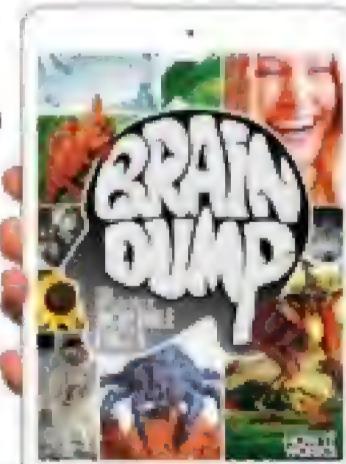
What does 'OK' actually stand for?

Emma P

■ OK stands for 'oll korreck', or 'ole kurreck', and comes from an abbreviation trend which was popular in Boston, MA, back in the 1830s. Other popular abbreviations at the time were NG ('no go'), GT ('gone to Texas') and SP ('small potatoes'). Many of the abbreviations were deliberately spelt incorrectly for humorous effect; for example, a predecessor of OK was supposedly OW ('oll wright'). OK gained widespread use when supporters of the American Democratic political party stated that it stood for the nickname of presidential candidate Martin Van Buren, aka Old Kinderhook. 'Vote for OK' became a snappy campaign slogan that popularised the use of OK across the USA. RS



■ The latest issue of Imagine's new, digital-only science magazine, Brain Dump, is now available from Apple's Newsstand. Overflowing with the snappiest, most authoritative and just downright awesome explanations to Earth's most important scientific questions, the current issue is the most informative and entertaining yet, answering a bucketload of amazing reader-submitted queries. Questions like, can we clone extinct animals? Why do we sleepwalk? How do Venus flytraps work? And why is electricity blue? All of these are answered along with many more. So to learn more about Brain Dump and the amazing content on offer in this and every issue, head over to the Apple Newsstand, pay a visit to the magazine's Facebook page at www.facebook.com/BraindumpMag or, alternatively, take a look on its Twitter stream @BrainDumpMag now.





Get running

Must-have kit to get off on the right foot

With the summer now drawing to a close, what better way to prepare yourself for the onslaught of the cold and overindulgent months than by getting in shape with a little running? While putting your body through the ringer is never easy, dedicated technology and clothes are making it more convenient and more comfortable than ever before, as we discover here.

Checklist

- ✓ Interactive scales
- ✓ Activity tracker
- ✓ Running shoes
- ✓ Headphones
- ✓ Sport socks
- ✓ Running T-shirt

EXTRAS

Three top resources to keep you on track with your running...



Running for Beginners

Price: £12.99/\$14.99

Get it from:

www.imagineshop.co.uk

Running for Beginners is a fantastic resource for anyone new to the sport. Written by dedicated fitness enthusiasts, this superb title is aimed at those looking to take up running for the first time, covering everything from training to gear and how to stay motivated.



Zombies, Run!

Price: Google Play £2.79/\$3.99; iTunes £2.49/\$3.99

Get it from: Google Play/iTunes

A fitness app that differs from the norm, Zombies, Run! casts you as a survivor of a zombie apocalypse as it supplies you with missions to complete and, as you might expect, zombies are constantly on the prowl attempting to grab you – as you'll hear through your headphones. If you don't want to be dinner, you'd better speed up!



LetsRun.com

Despite its rather Nineties-looking design, www.letsrun.com is a veritable mine of running info. Trawling the globe for current running news on a daily basis, the website enables you to follow specific athletes and events, while the affiliated forum is famed for its advice and analysis.

1 Measuring BMI

Fitbit Aria Wi-Fi Smart Scale

£99.99/\$129.99

www.fitbit.com

If you're serious about getting in shape be prepared for a long journey. Weight loss and muscle tone don't just happen over night. Luckily, the Fitbit Aria Wi-Fi Smart Scale makes this more bearable, measuring, storing and tracking up to eight users' body fat percentage, weight and body mass index (BMI). This data can be wirelessly streamed via Wi-Fi to a PC, where included software converts it into a variety of graphs and charts. All together this is an excellent motivational fitness tool.

Verdict:

2 Activity tracking

Fitbit Zip

£49.99/\$59.95

www.fitbit.com

There's a bounty of activity trackers on the market today, ranging from £20 right through to £200 or even more. The Fitbit Zip comes in right at the sweet spot for this category of devices, offering a small and stylish activity tracker for a penny shy of £50. Capable of recording a runner's steps, distance and calories spent, the Zip is versatile, while its ability to wirelessly sync with a computer or smartphone makes keeping track of progress more straightforward than ever.

Verdict:

3 Lightweight foam

New Balance 1260v3 shoes

£124.99/\$144.99

www.newbalance.com

When running, your feet are the most active part of your body so a good pair of running shoes is vital. A brand-new entrant to New Balance's catalogue of fitness-focused sport shoes, the 1260v3s are an excellent example, offering superb support and cushioning. In addition, the trainers' Acteva Lite foam is 24 per cent lighter than other foams and provides enhanced resistance to compression under impact, granting better spring and comfort over long distances.

Verdict:

4 Sweat proof

JVC HA-EB75s headphones

£12.99/\$12.95

www.amazon.com

Running headphones need two things: a secure fit and water resistance. This is because there's nothing more annoying than having earphones constantly jiggling free and falling out when you're trying to run, or packing up the first time it rains or they get sweaty. The great-value-for-money JVC HA-EB75s deal with these criteria well thanks to special ear clips and moisture-resistant earbuds, while a neodymium driver unit delivers surprisingly decent audio to boot, with a good level of bass.

Verdict:

5 Dual-layer socks

1,000 Mile Fusion sport socks

£11.99/\$10.00

www.1000mile.co.uk

Often overlooked when it comes to running kit, the average sock is actually not well suited to the discipline and, as a result, they can often cause blisters and red-raw skin. The 1,000 Mile Fusion sport socks go a long way to rectify this predicament, with a two-layer construction, padded Achilles' tendon support structure and moisture-repellent Tactel inner material keeping your feet in prime condition during exercise. Of course, at £12 a pair, this luxury comes at a premium.

Verdict:

6 Muscle support

Salomon EXO S-Lab Zip T-shirt

£80/\$100

www.salomon.com

The EXO S-Lab Zip tee is not only very comfy to wear thanks to its flatlock seams, but also loaded with smart tech. Firstly the EXO has been designed to improve upper body posture, with areas of compression and support improving oxygen intake while running. Secondly, the inclusion of Salomon's Actilite II Stretch Mesh means that any sweat is repelled fairly quickly. Lastly, by using different materials, such as polyester and spandex, each area of the T-shirt is designed for optimum movement.

Verdict:

Tablet takedown

We get hands-on with three of the top tablets on the market to see which one delivers the best results

1 Nexus 7 (second gen)

Price: £199.99/\$229

Get it from: www.google.com/nexus/7

Okay, let's be upfront about this one. The second-gen Nexus 7 is an excellent tablet and it's easy to see why many are insisting it's currently the best in the world. It's slick, powerful and without doubt definitive proof that the 17.8-centimetre (seven-inch) form factor works, offering a lightweight slate upon which media, games and online services all shine.

This is largely due to its impressive technical specifications. Packing a Snapdragon S4 Pro Krait 300 1.5-gigahertz CPU, Adreno 320 400-megahertz GPU, two gigabytes of DDR3L RAM and an IPS LCD capacitive touchscreen with a resolution of 1,920 x 1,200 pixels (323 pixels per inch), the Nexus takes almost every other tablet to the cleaners in terms of performance. Indeed, the only other tab that comes close is its bigger brother, the Nexus 10.

This technical prowess translates into excellent usability, with the Android 4.3 Jelly Bean operating system running incredibly smooth and apps launching all but instantaneously. Its low weight of just 290 grams (10.2 ounces), along with its even thinner profile compared to last year's model - 8.7 millimetres (0.3 inches) thick, make holding it with one hand a breeze. This really is the king of today's tablets.

Verdict:

2 iPad mini

Price: £269/\$329

Get it from: store.apple.com

We're huge fans of the 17.8-centimetre (seven-inch)-sized tablet and so we are quite happy declaring the 20-centimetre (7.9-inch) iPad mini the best that Apple has ever made. It is thin, super-sleek and simple to use, with Apple's walled garden of an ecosystem familiar and well-structured as ever. However, in light of some recent releases from Apple's main rival, Google, the iPad mini doesn't come out of this head-to-head as unscathed as you might expect.

Technically the mini loses out to the similar Nexus 7 on every front, with its one-gigahertz, dual-core A9 CPU, PowerVR GPU, 512-megabyte RAM and 1,024 x 768 pixel screen all trumped. In fact, the screen may be the most disappointing aspect of the iPad mini, with the modest 163-pixel-per-inch fidelity almost doubled by the Nexus 7. At least the battery life is good, with a solid ten hours on offer.

As ever though, in terms of operating system and applications, this pint-sized iPad punches hard. The curated experiences of the App Store and iTunes remain superb, while iOS 6 - currently updated to 6.1.3 - makes navigating apps, emails, menus and much more both intuitive and enjoyable. This user experience is somewhat checked by the price though, with the Wi-Fi-only, 16-gigabyte model costing £70 (\$100) more than Google's Nexus 7.

Verdict:



Highest-res screen

The Nexus 10 comes with the highest-resolution display currently available on a tablet: a 2,560 x 1,600px Super PLS panel. The fact that the monstrous resolution is crammed into just 25.4 centimetres (ten inches) of screen means that everything appears incredibly sharp.

Densest ppi

Despite the fact its big brother, the Nexus 10, takes the crown for the highest overall resolution screen, the Nexus 7's panel technically has the highest ppi density, cramming in a mighty 323. The human eye can't really differentiate over 300 pixels per inch, so this is basically the clearest display ever made.

3 Nexus 10

Price: £319/\$399

Get it from: www.google.com/nexus/10

The bigger brother to both the first- and second-generation Nexus 7s, the Nexus 10 is a powerhouse of a tablet. Armed with a monstrous 2,560 x 1,600 pixel screen - that sort of resolution is typically the reserve of 76-centimetre (30-inch) computer monitors, a 1.7-gigahertz, dual-core A15 CPU, two gigabytes of DDR3 RAM and a lithium polymer 9,000mAh battery, the 25.4-centimetre (ten-inch) Nexus is the most powerful Android tablet on the market.

With the 10's larger proportions, compared with the mini and the Nexus 7, there comes an additional tier of direct competitors - most obvious being the iPad 4. However, aside from overall build quality - which the iPad 4 wins due to its high level of metal and glass as opposed to the Nexus's polycarbonate - it is much the same story as with the Nexus 7 and the iPad mini. The 10's tech destroys that of the iPad 4 - and does so a good deal cheaper - but Apple's slick OS and app functionality pip that of the Android offering.

Whether or not the Nexus 10 or Nexus 7 is the better device depends on what type of user you are. The size and power of the 10 is immense and if you consume large quantities of high-definition media then the 1080p screen and long battery life make it ideal. However, if you're a more casual all-round tablet user who needs it for web browsing on the go etc then the lighter Nexus 7 series makes more sense.

Verdict:

ON THE HORIZON

We highlight four other items to look out for in the near future

Sony Bravia X9

The first reasonably affordable 4K TV - and affordable is used loosely as it's still £4,000 - the Bravia X9 promises HDTV-busting resolutions. Whether or not the 3,840 x 2,160px screen is enough to justify the sort of outlay that could buy a decent second-hand car remains to be seen.



New iPhone

As we enter the autumn months a familiar fruit begins to form ahead. It is, of course, iPhone manufacturer Apple, which has a tendency to unveil the latest iteration of its all-conquering iPhone in the latter part of the year, with the follow-up to the iPhone 5 now keenly anticipated. Whether or not this device is an update or an entirely new breed of smartphone will only become apparent in the coming months.

NVIDIA SHIELD

Finally released, we have been itching to get the NVIDIA SHIELD handheld gaming console for ages. The system, which looks like an Xbox One controller with a 12.7-centimetre (five-inch) screen attached, is packed with some serious hardware - eg Tegra 4 processor - and can access a wide variety of PC and Android video games. We have a bit longer to wait until one arrives at HIW HQ though.



RetroN 5

Another slightly anticipated piece of gaming tech is the RetroN 5, a crazy console that has been designed to accept NES, SNES, Sega Genesis, Famicom and Game Boy Advance cartridges. The system, which will enable you to replace five retro consoles with just one sleek box, also delivers improved video and audio thanks to its HDMI support. No release dates have yet been confirmed.

Hit a hole-in-one

With this quick guide to golf, you'll soon get into the swing of taking a shot...



1 Read the environment

Before picking up a club you need to gauge the shot. Wind, for example, can have a major bearing on where you should aim and your intended target's elevation will dictate which club you use. For instance, if the green is uphill from your position then you'll need to select a stronger distanced club (say, a four-iron rather than a six-iron). Equally if the wind is blowing left to right, you will have to aim farther left to compensate.



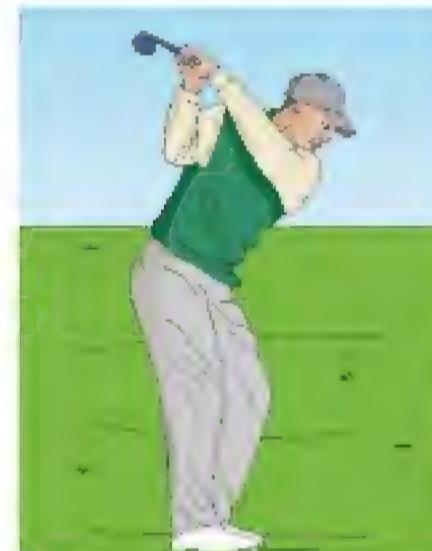
3 The right stance

Start by placing your feet shoulder width apart and parallel to the target's line (the direction to the green). While the back foot should remain 90 degrees to the target, the front foot should be flared out towards it by about 20 degrees; this will help to rotate your body during the foreswing. For ball positioning, the stronger the club you are using, the farther forward the ball needs to sit in the gap between your feet.



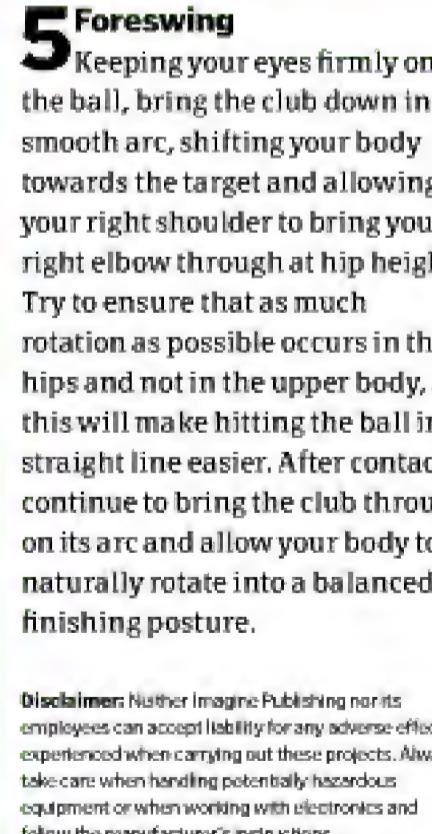
2 Get a grip

You won't hit anything with much success unless you know how to hold a golf club. There are different grips, eg overlapping, interlocking and baseball types. For the most common grip (overlapping) take hold of the shaft with your left hand, place the little finger of your right hand between the middle and forefingers of the left, and then close both around the club ensuring that your thumbs are aligned downwards.



4 Backswing

Before hacking at the ball, take some time to position the club at the top of your swing. To do this, draw your club back slowly, brushing the face along the grass for as long as possible. Once the club leaves the ground maintain a smooth arc until the club is positioned above your head and pointing forwards along the target path. Do not overextend as this will likely lead you to cut across the ball's face and mishit it.



5 Foreswing

Keeping your eyes firmly on the ball, bring the club down in a smooth arc, shifting your body towards the target and allowing your right shoulder to bring your right elbow through at hip height. Try to ensure that as much rotation as possible occurs in the hips and not in the upper body, as this will make hitting the ball in a straight line easier. After contact, continue to bring the club through on its arc and allow your body to naturally rotate into a balanced finishing posture.

NEXT ISSUE
- Make pancakes
- Scuba dive

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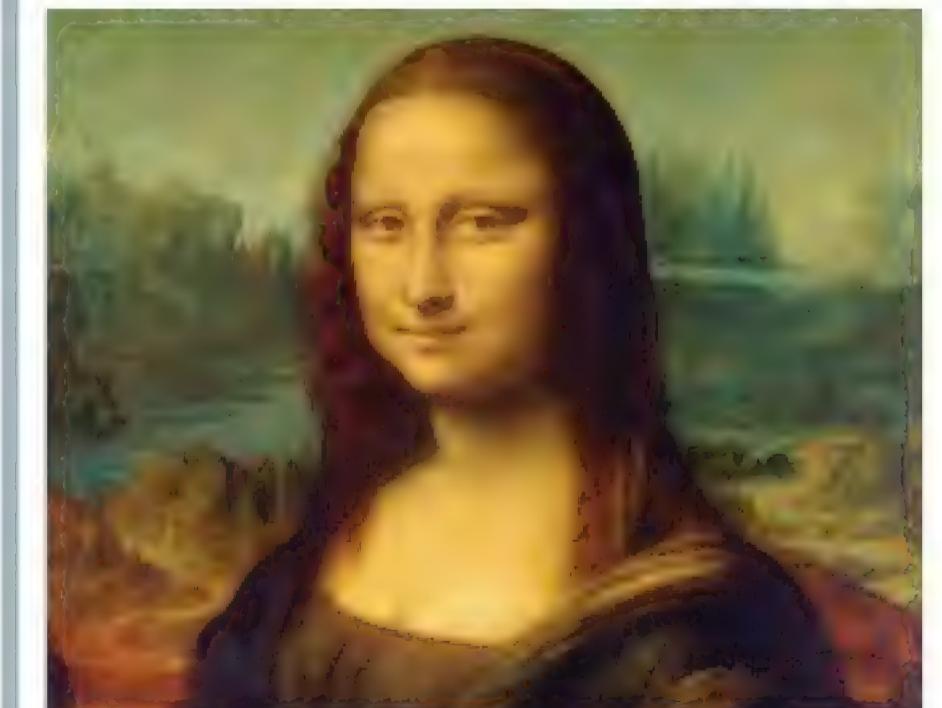
QUICK QUIZ

Test your well-fed mind with ten questions based on this month's content and win a model of a Type 45 destroyer from Airfix!



Answer the questions below and then enter online at www.howitworksdaily.com

- How many pixels per inch does the screen on the second-gen Nexus 7 have?
- How many missions did the Space Shuttles complete before they were retired?
- Roughly how long was a fully grown Ankylosaurus dinosaur in metres?
- On what date was the Mona Lisa painting stolen from the Louvre in Paris?
- What is the displacement of the British Type 45-class destroyer in tons?
- How much will the ESA's JUICE mission to Jupiter cost in US dollars?
- How many times weaker is the gravity on Triton compared with Earth?
- What size battery does the Xperia Z Ultra waterproof smartphone have?
- How many quills does the North American porcupine have on average?
- The Spanish Steps in Rome comprise how many steps?



ISSUE 50 ANSWERS

- 250mn years
- New Zealand
- 98%
- 1893
- 5,40
- John Roebling
- 8.1858
- 6,400km
- 1959

Get in touch

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WIN!

We enjoy reading your letters every month, so keep us entertained by sending in your questions and views on what you like or don't like about the mag. You may even bag an awesome prize for your efforts!

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The writer of next issue's 'star' letter will win themselves a Visionary FirstView Starter Telescope. Visit [www.howitworksdaily.com](#) for details.

No such thing as coincidence?

I just received issue 49 of your magazine in the mail and I am amazed. At school we are studying megacities... And lo and behold, you have an article about megacities in your magazine. In science we are looking at mould. You have an article about mould in your magazine. In the holidays we visited Surfers Paradise [in Queensland, Australia]. You had an article in the How To... section about surfing. In the holidays we also went to Dreamworld [theme park in Queensland]. There was a ride that my dad said used centrifugal force. I didn't understand it when he tried to explain, but thanks to the Brain Dump, I now know what centrifugal force is. Keep up the great work! Maggie



Letter of the Month

A Noble cause

Dear HIW,

Huge respect for Richard Noble and the work he does in pushing the boundaries of engineering. However, in issue 50 of How It Works Richard was interviewed as saying 'the British haven't really done anything astonishing in engineering terms since Concorde', but this is not true. Here in Barrow-in-Furness at the shipyard owned and operated by BAE Systems we have designed and are building the most complicated machines in the world: Astute-class submarines. In fact, it has been stated by our US cousins that this engineering feat has resulted in machines more complicated than NASA's Space Shuttle. Surely there cannot be a better example of the huge engineering skill

existing in this country than these magnificent vessels. Russ Rushton

There's no denying a great many significant feats of engineering excellence were born from the minds and hands of Britons - and we've no doubt Richard Noble appreciates this too. Many of the letters we receive each month are from youngsters keen to share their fascination and thoughts on the subject of engineering so long may people like Noble inspire new generations. We enjoy hearing of the UK's pride in its achievements and so we'd like to award you Letter of the Month.

You honestly wouldn't believe the number of letters we get like this, Maggie. It's genuinely bizarre how often such coincidences happen. Maybe we're just tuned in to what our readers want to know...

Three cheers for musketeers!

My entire family enjoys reading your magazine and it has been a particular pleasure to watch my son - now 11 - dive for it as it lands on the mat each month. In this month's edition [49] there's a piece on musketeers. In the 'Sword' annotation on the diagram, it says that musketeers 'were trained to fight both on horseback like dragoons and on foot like infantry'. Felix would like to point out that dragoons rode

to battle and then fought as infantrymen. Meanwhile, right or wrong (Wikipedia suggests the term's meaning changed over time), I would simply like to thank How It Works for engaging his interest to such a degree. Jamie Hussey

Thanks for your letter, Jamie (and Felix) - and you are both absolutely right. Initially, dragoons would ride into battle and dismount before they started fighting. However, they did eventually adopt cavalry tactics and were able to fight from horseback as well, so the definition of dragoon did evolve over the years. We're glad that your family enjoys the magazine, and we are all super-impressed by Felix's keen eye for detail!

Diabetes to get the HIW treatment

Can I start by saying that I am a subscriber and I absolutely wait without patience for the next copy of How It Works to land through my letterbox.

I was wondering if you could do a small feature for me? I am a diabetic and every day I have to test my blood on numerous occasions. You prick your finger with the lancet then put the drop of blood onto the test strip. You then insert the test strip into a small blood meter that gives an almost-instant readout revealing your blood glucose levels.

How do these strips work? How does the blood reader analyse the small sample of blood so quickly? Thank you for the

© Thomas McDonald/Thinkstock

"I can occasionally surprise my five grandchildren with little bits of technical knowledge"

great learning tool that your magazine has become for me. It certainly keeps the old grey matter working. Joe

We've had a few queries about this. You'll read it here next issue, Joe.

of those rich books. It always makes us proud to hear about the various benefits our readers get from reading and sharing the information we provide, so thanks.

A handy article

I receive your magazine monthly and read it cover to cover. I really enjoy it and it is so informative. This past Mother's Day I had a horrible accident to my left hand with a long surgery to repair it. Unfortunately I now have numbness to two of my fingers and the side of the hand which hopefully will be normal again within a year. My question is, was an issue of How It Works ever published with an article looking at the hands? If so I would like to obtain a copy.

Charlene Palmer

We're sorry to hear about your hand, Charlene, and hope you're recovering well. We did a two-page feature on the anatomy of the hand back in issue 14, which unfortunately is out of stock at our eShop. However you can still download the digital edition to a smartphone or tablet - just head to [www.greatdigitalmags.com](#).

Thanks for your email. Publications like the Eagle inspired us so it's great to hear that reading this is evocative

What's happening on... Twitter?

We love to hear from How It Works' dedicated followers. Here we pick a few tweets that caught our eye this month...

HP987654321 @HP987654321 @HowItWorksmag If the issues get better every month then the next issue must be incredible! Because issue 50 was AMAZING!

Charisma @charis_webster @HowItWorksmag just seen latest issue BOSH that's a cover! I like it :)

Damian Butt @ImagineMD @HowItWorksmag Essential reading for the train - awesome '50 Greatest Inventions' feature

Tom R @blockswitch WOOOOO! Just got the new @HowItWorksmag 50 GREATEST INVENTIONS

Sarah Hamilton @sarahisobell Reading the latest copy of @HowItWorksmag I've got an assignment on the musketeers so it's perfect timing!

Steve Bowbrick @bowbrick I like it when they have the 'Learn About' box on the front cover of @HowItWorksmag

Wadil Merhy @wadilmerhy @HowItWorksmag My personal favourite! I never skip an issue

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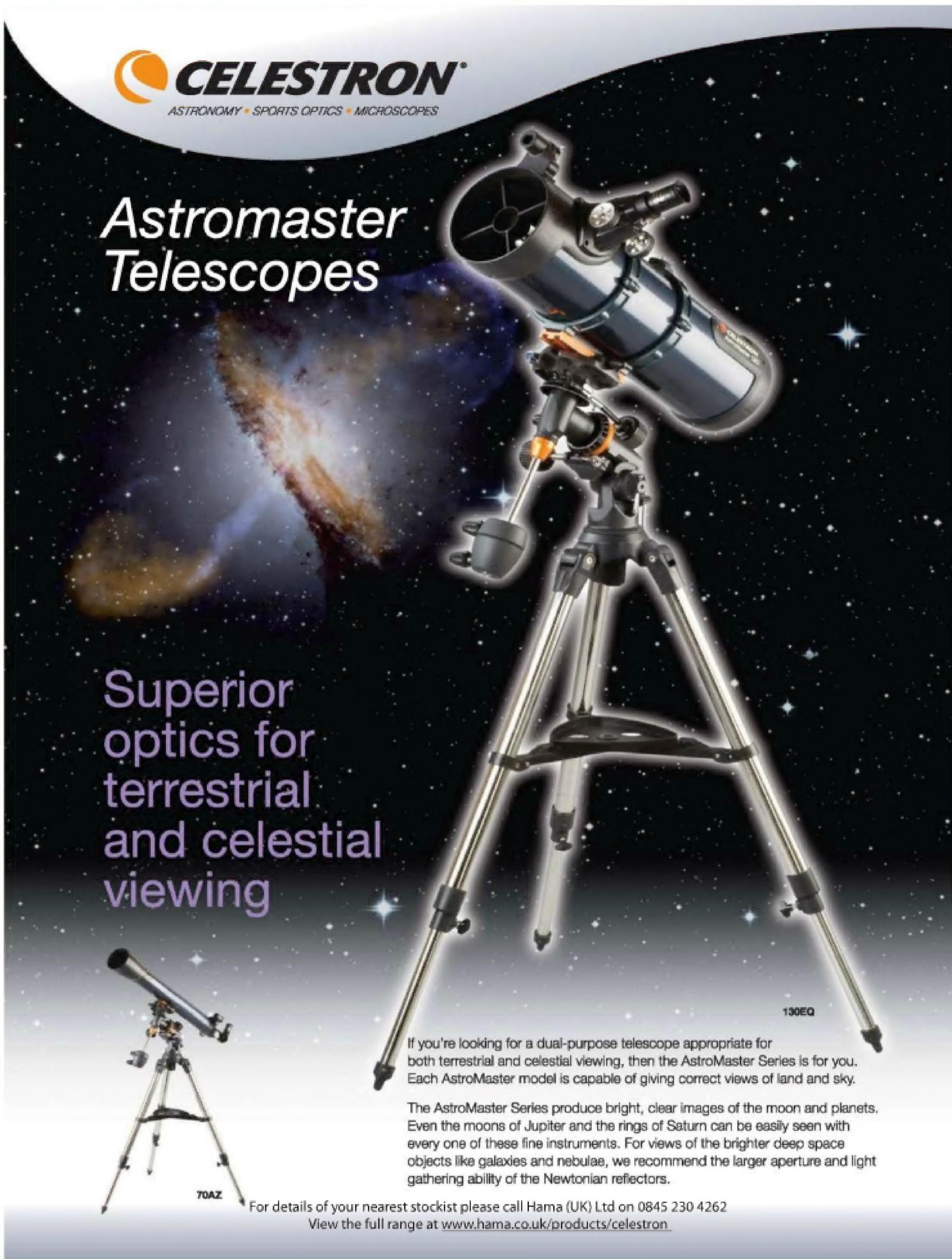
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To learn more about diabetic glucose test kits, be sure to check out the next issue!

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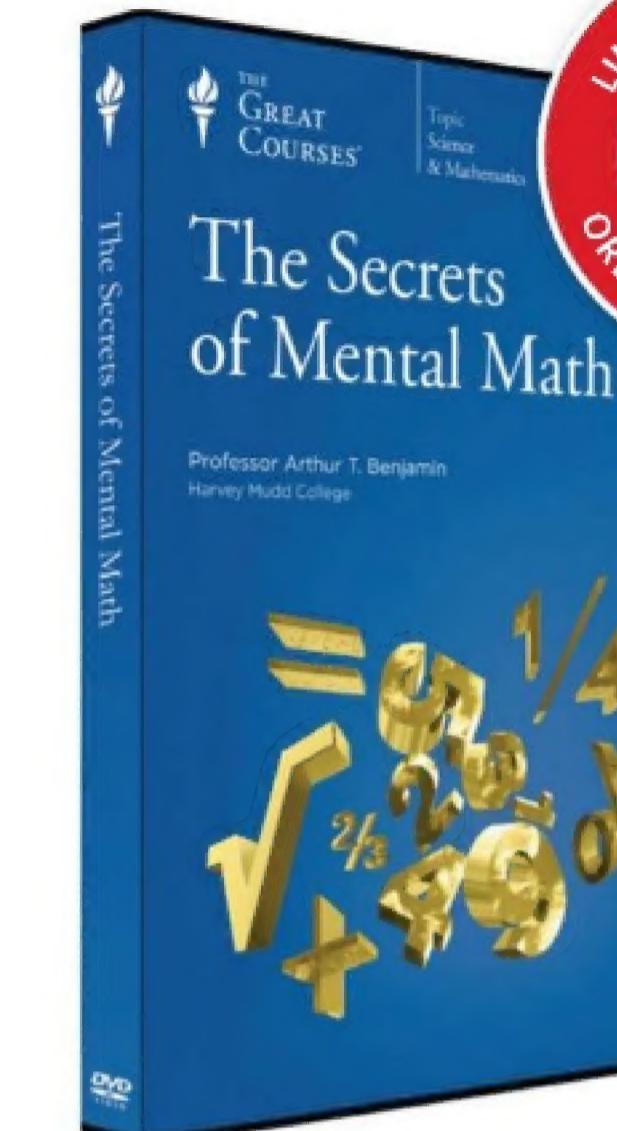
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